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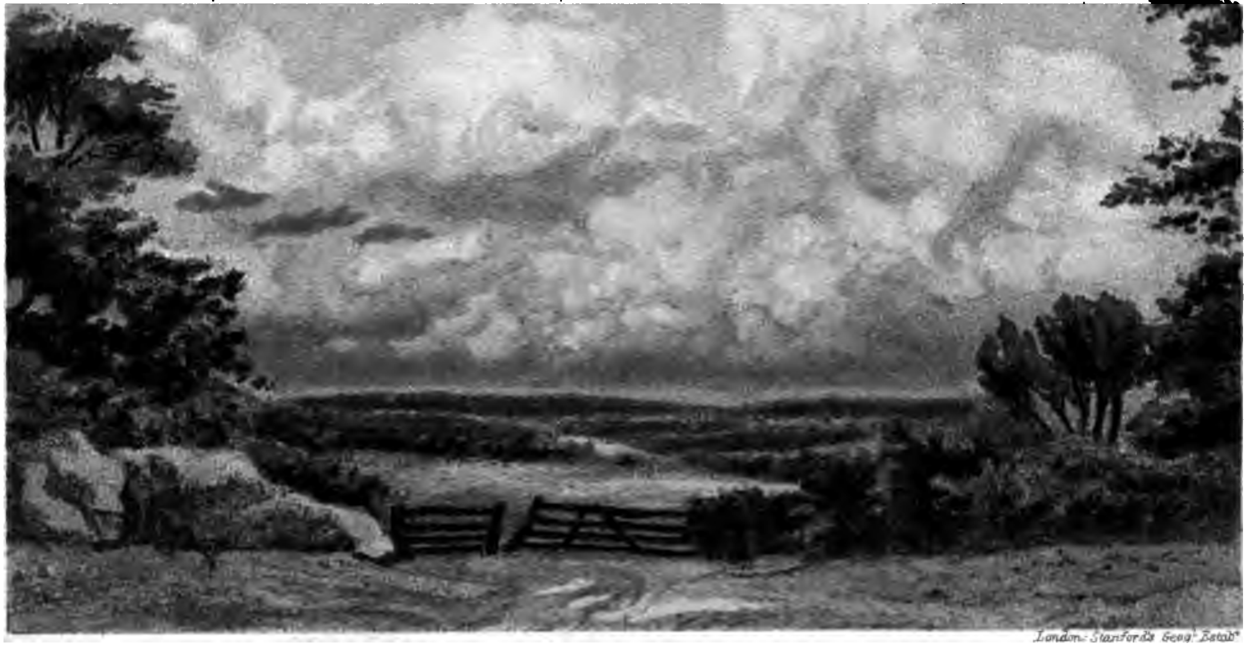
CLOUDLAND

Plate I.



London: Stanford's Geog.l Estab.t

CUMULO - NIMBUS

CLOUDLAND

A

STUDY ON THE STRUCTURE AND CHARACTERS
OF CLOUDS

BY

REV. W. CLEMENT LEY
M.A., F.R.Met.Soc.

*WITH NUMEROUS COLOURED PLATES, PHOTOGRAPHS,
CHARTS, AND DIAGRAMS*

LONDON: EDWARD STANFORD
26 & 27 COCKSPUR STREET, CHARING CROSS, S.W.
1894

ASTOR
NEW

Thou on whose stream, 'mid the steep sky's commotion,
Loose clouds like earth's decaying leaves are shed,
Shook from the tangled boughs of heaven and ocean,

Angels of rain and lightning ! there are spread
On the blue surface of thine airy surge,
Like the bright hair uplifted from the head

Of some fierce Mænad, even from the dim verge
Of the horizon to the zenith's height,
The locks of the approaching storm. Thou dirge

Of the dying year, to which this closing night
Will be the dome of a vast sepulchre,
Vaulted with all thy congregated might

Of vapours, from whose solid atmosphere
Black rain, and fire, and hail, will burst : O hear !

SHELLEY, *Ode to the West Wind.*

PREFACE

THE task which has been attempted in the following pages is one which is beset with many difficulties. In the first place, clouds are in themselves inaccessible and intangible objects which cannot be examined by direct experimental means, so that we have to rely mainly upon theory based on careful observation. It is very difficult to treat of a vague and complicated subject in any but a vague and complicated manner; and so intricate are the causes to which clouds and winds are due, and so intimate is the connection between them, that it would not be possible to treat of one without having to deal with the other, or to pursue a study of the one without a study of the other. Secondly, the subject itself is one which has received scant attention by meteorological writers, who seem to have considered that the science of meteorology consists entirely of investigations into the variations of temperature, pressure, and wind at the earth's surface, and that the thermometer, barometer, and weather chart are the only things necessary to make a man a competent meteorologist, and who have been apt to forget that the barometer and thermometer, after all, only show the variations of pressure and temperature at the earth's surface over a very small local area, and that the weather chart is merely the result of a large number of individual observations. Lastly, in spite of the great importance of the science, especially in a country on whose fickle climate so much depends, it is very few indeed out of the number whose interests are concerned who care to study practically the cause and effect of variations in the atmosphere.

The main object, then, which has presented itself to the author has been to help and interest the individual observer, and he believes that, just as individual observation has always been the force which has built up and accelerated the growth of a rising science, so will the improvement of individual observations be the chief factor in aiding the growth of meteorology. He has therefore abstained from any description of instruments, and, as far as possible, from detailed accounts of well-known scientific phenomena, and has assumed that the reader possesses some slight ordinary knowledge of meteorology. The difficulties he has had to encounter have not only been those mentioned above. Long illness, which finally prevented him from completing the work as he had originally intended, was the greatest obstacle. But if he has in any way succeeded in rendering easier the task of observers at meteorological stations, or of adding any interest to, or throwing any light on, the subject as a whole, his task will have been fully accomplished.

The classification of clouds, the theories of their formation, and the other subjects dealt with are the outcome of lifelong observational study, but, owing to the author's ill-health, I have been obliged to arrange and set these in order, and have in one or two cases added explanations and diagrams where he had intended to do so; but this has not been done without an intimate knowledge of the author's opinions and intentions, and careful consideration of other works on the subject. The reader's pardon is craved for any errors and appearance of incompleteness which must thus necessarily occur.

Much valuable assistance has been obtained from the works of other authors; more especially may be mentioned the works of Professor William Ferrel, the greatest of modern meteorologists. References have, as far as possible, been made, and in those cases in which they have not the author's apologies are due.

The author particularly wishes to express his thanks to Mr. Arthur Clayden for a series of beautiful photographs which he has kindly given him permission to reproduce. These have been supplemented by a few reproductions of rough water-colour sketches made by the author some years ago.

C. H. LEY.

LONDON, 30*th July* 1894.

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CHAPTER I

THE ATMOSPHERE

1. Clouds have been correctly defined by Dickson as "portions of the atmosphere which, from natural causes, have become temporarily visible." They are aggregates of particles floating in the air, generally, but not necessarily, particles of water or ice. It will therefore be useful, before proceeding to analyse the various forms of cloud and their bearing on weather, to try and fix in our minds some ideas of the nature of this atmosphere and of the processes taking place in it which affect the formation of cloud.

2. For the actual constitution of ordinary impure air it will be sufficient to remind the reader that it contains by volume about 78 per cent of nitrogen, 20 per cent of oxygen, a variable quantity of aqueous vapour (usually about 1½ per cent), a little carbonic acid and other gases, and lastly, a variable but important amount of dust of various kinds.

Now the most important of these constituents, as regards the subject of which we are going to treat, are the variable ones, viz. the aqueous vapour and the dust particles. The powers which are possessed by these two factors in altering the conditions and affecting the character of weather and climate are perhaps not sufficiently realised. But before dealing with these it will be necessary to say a few words on the variation of temperatures and pressures through the atmosphere, even at the cost of repeating universally known and understood facts.

3. The pressure of the atmosphere at any point is simply the weight per unit of area of the whole column of air which rests above that point. Thus the higher we rise in the atmosphere the less the pressure will be. And if the pressure and density of the atmosphere were the same throughout as at sea-level, and the temperature were also uniform, the whole height of the atmosphere would only be about 5 miles. But these three factors all decrease rapidly with increase of altitude, and react upon one another in such a manner as to make it impossible to absolutely determine the height of the atmosphere. From other considerations we suspect that this height must be at least 100 miles or more, although, of course, we cannot say that it ends at any particular level, for it grows gradually more and more rarefied until it disappears in space. The fact that the envelope of air exerts a weight on the earth's surface of about eighty billions of tons may give us some notion of the vastness of this envelope.

4. For small altitudes and in still atmosphere we may take the pressure as decreasing at the rate

of 1 in. per 1000 feet increase in elevation, and the temperature as decreasing at the rate of ·216° Fahrenheit for every 100 feet increase. But these rules are liable to considerable variation. For instance, in the cold winter nights of the temperate zones, when the earth loses heat rapidly by radiation into space, the temperature distribution may become inverted, the base of a column of air becoming colder than the upper portion. On the other hand, during the afternoon of a hot summer's day, and in some other conditions, the decrease of temperature with elevation is much greater than that given above. The pressure distribution also varies considerably. There are extensive permanent areas in different parts of the globe in which the pressures at the earth's surface are less, and decrease at a less rapid rate with altitude, than those on either side of these areas. There are also local wandering areas of low pressure called cyclones, and local areas of high pressure called anticyclones. These will be treated of in later chapters. It will be sufficient here to state that the unequal distribution of pressure and temperature over the globe disturbs the atmospheric equilibrium to such an extent as to cause strong permanent as well as local currents.

These movements are not only horizontal, but also more or less vertical, interchange taking place between the upper and the lower layers of air. It is necessary to mention one result of this interchange which plays a conspicuous part in some of those phenomena which are the subject of the present work.

5. Whenever a gas is subject to rapid compression, whatever the nature of the force which produces the compression may be, the temperature of the gas is raised. And conversely, whenever a gas undergoes a sudden expansion, its temperature is correspondingly lowered. Consequently, if a current of dry air is ascending rapidly, its decrease of temperature is very rapid, not only on account of its increasing distance from the earth, but also on account of its expansion due to decrease of pressure. The rate of this decrease in such a current is found to be about ·54° Fahrenheit for each 100 feet of ascent (·98° C. per 100 m.). It follows from this that if the distribution of temperature with altitude in quiet air be about that mentioned in § 4, a column of ascending air will be quickly cooled down to a point below the temperature of the surrounding quiet air, and its density becoming greater than that of this air, the column will quickly fall back again. We may for convenience call such a condition one of "stable equilibrium." On the other hand, if, as in the example given above of a hot summer's day, the temperature of the still air decreases abnormally with increase of altitude, the ascending column may lose heat less rapidly than the still air around it, and consequently it will continue to ascend. To such a state we can apply the title "unstable equilibrium." It will be obvious that this state is not likely to exist at a great altitude above the earth.

It will also be seen that in the state of stable equilibrium a downward motion commencing in any layer of the atmosphere would, like an ascensional movement, be speedily arrested, while in a state of unstable equilibrium it will tend to continue downwards. It should be borne in mind that while the atmosphere is undisturbed, whatever the change of temperature dependent on altitude may be, no vertical movement of the atmosphere will take place, whether the atmosphere be in a state of stable or unstable equilibrium, until some disturbing force begins to act in one direction or another. Any approximately vertical current which tends to turn a portion of the atmosphere upside down or to effect an interchange between its lower and higher strata may be called an "inversion movement" or "current of inversion."

6. We now have to consider one of the primary causes of these disturbances in our atmosphere, viz. aqueous vapour. This vapour is a compound gas, and were it similar to the simple gases in the atmosphere, its effects would not be nearly so complicated. But in the first place, its density is only about half that of dry air, so that if it were to remain a gas, it would ascend to a height much greater than that of our atmosphere. In the second place, with decrease of temperature it does not remain a gas, but becomes condensed into water and congealed into ice.

Now the greater the temperature of any portion of air, the greater its capacity for holding water-vapour, or the amount of water-vapour which such a portion of air can hold as water-vapour depends on its temperature. Therefore, if the temperature be lowered, water-vapour will be condensed on any solid surfaces with which it comes in contact until the amount left is the maximum which can be held at the new temperature. The temperature at which any portion of air commences to deposit vapour in the above manner is termed its "dew-point." Also the pressure exerted by aqueous vapour is a measure of the amount of this aqueous vapour, and is usually but not happily termed the *tension* of aqueous vapour. The proportion between the actual vapour-tension at any particular temperature and the maximum vapour-tension possible at that temperature is called the "relative humidity."

Hence the amount of aqueous vapour which can exist in any portion of the atmosphere diminishes very rapidly with decrease of temperature, so that we have, roughly speaking, only to ascend about 6000 feet (1830 m.) to get above one half the whole amount of vapour contained in the atmosphere, while at about 25,000 feet (7620 m.) the whole amount of vapour is very trifling.

The distribution of water-vapour at the earth's surface of course depends greatly on the respective geographical position of water and land surfaces, and of damp and dry surfaces generally. Vapour is therefore most abundant over the oceans and the great lakes and the land adjacent to them. As water gives off vapour in proportion to its own temperature on the one hand, and to the capacity for additional vapour in the air on the other (which depends on the temperature of the air), the amount of vapour over a sea surface in the tropics is greatly in excess of the vapour at the poles. And, considering the distribution of temperature over the globe, it is obvious that a very small proportion indeed of the inter-tropical vapour can ever pass into the temperate zones during winter.

7. We can now easily picture to ourselves some of the simplest of those conditions under which the vapour present in the atmosphere is condensed into particles of water or congealed into those of ice. These processes must evidently take place whenever a layer of moist air has its temperature sufficiently lowered. This result may be attained when the dust particles in the air lose heat by radiation into space, or when the surface of the earth itself loses so much heat by radiation that the vapour immediately above it becomes mist or fog, or when fog or cloud itself radiates heat into space and has the temperature of its upper surface lowered. Again, a similar result will be effected when a warm moist wind moves over a relatively cold surface, such as the ocean surface in the summer of the temperate zone, or when such a wind travels into higher latitudes, and therefore has its temperature diminished, or into lower latitudes within the tropics whenever the temperature near the tropic is greater than that near the equator. Also when the temperature of a moist current is diminished by simple expansion, as where a damp wind has to cross a range of mountains, producing the cloud-caps familiar

to all observers. Also where a cold wind intermingles with a current of warmer air with a temperature near the dew-point.

8. Remembering the law that condensation produces heat, and expansion absorbs heat or produces cold, we are now in a position to understand what the effect of the presence of aqueous vapour will be in an "inversion movement" taking place in an atmosphere in "unstable equilibrium" (§ 5). We imagine that from some cause or other, whether this be difference of pressures or rise of water-vapour itself, or accidents in the earth's surface, or other causes, a current of air is rising in a more or less vertical direction through layers of air in which the tensions of aqueous vapour approach their maxima. Here at some level above the earth's surface, dependent on distribution of temperature and previous tension of vapour, a great amount of vapour will be simultaneously condensed, forming the basal portion, often level, of a body of cloud. Immediately this condensation occurs the air layers in which it takes place are heated, expand, and, rising, further augment the ascending current, the temperature again falls, and condensation takes place in layers of air above, and so the process goes on. Now it is evident as we rise higher and higher into colder layers of air the heat given out by condensation will become less and less, because these layers contain less water-vapour. Also as we rise higher and higher we shall have reached layers of air which are at such great altitude that they are

not much affected by radiation from the earth, and that therefore are in a state of "stable equilibrium." Our ascending current will therefore have lost the accelerating effects of condensation, and will have become much colder and denser than the air on all sides of it. It will therefore flow outwards and downwards, and cooling the air in its descent, condensation will take place in a downward direction, water particles pouring in a stream down the exterior surface of the cloud until the current is finally checked at some lower level by the increasing heating effects of this condensation. And it will be fairly evident that such a process may take place, although in a much less degree, in an atmosphere in "stable equilibrium." The cloud in this case will not attain nearly such great vertical proportions. Thus in winter and on cool summer days we are not likely to see those great masses of cloud which produce heavy local thunderstorms. Fig. 1 is a rough representation of a cloud formed in the manner above described, the length of the arrows intending to represent roughly the velocities of the currents.

9. We thus see how great are the effects produced by the presence of aqueous vapour in "inversion movements," and how truly this presence may be said to make mountains out of molehills. The following data may give us some idea of the work done by condensation of vapour:—

"For one-tenth of an inch of rain precipitated from the lowest mile of the atmosphere we should have a rise of temperature of this lowest mile amounting to 6° Fahrenheit (3·3° C.), quite enough to produce a powerful ascending current. The ascending current expanding and cooling produces further condensation. The heat developed over one square foot of the earth's surface under these conditions is equivalent to the work done at the rate of one horse-power continued for twelve minutes. Over one square mile this would be ten million horse-power for half an hour. A fall of one-tenth of an inch of rain over the whole of Great Britain gives heat equivalent to the work of one billion of horses for half an hour!"

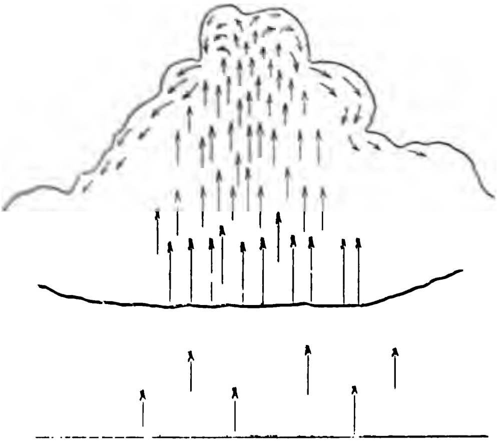


FIG. 1.—INVERSION MOVEMENT PRODUCING A CLOUD.

Statements like the above appeal vividly to the imagination, but it is unfortunate that the work done by the conversion of vapour into cloud without rain cannot be definitely measured. If it could, we might then be able to "cap" the above with a row of figures which would dwarf it into insignificance.

10. Having dealt at some length with inversion movements, we must now describe another process which has a great influence on cloud formation. It has already been stated that the pressure distribution is not equable all over the globe, but that there are various areas of low and of high pressure. These will be treated of hereafter, but it will be necessary here to state that they produce more or less horizontal currents over the globe, which move over one another with varying velocities and directions. Now the nearer a current is to the earth's surface, the more it is retarded by friction with the earth. The amount of this friction depends on the velocity of the current, and on the irregularities of the earth's surface. Every one is familiar with the fact that the wind often blows with greater strength on the open surface of the sea than at inland localities, and over an open plain than over broken or well-timbered country; also with the fact that at the summit of a tower more wind is experienced than at the base. This retardation, caused by friction with the earth, makes itself felt at a very great height. Consequently, as we rise higher, and the density of the air becomes less, the currents move faster.

Now the effects of friction are similarly felt at the contiguous surfaces of two currents moving with different velocities and directions. It has been found that these effects are similar to those produced by the action of wind over water, but, generally speaking, of far greater magnitude.

If two horizontal or nearly horizontal currents, differing in velocity, or in direction, or in both velocity and direction, move the one over the other, the particles of air will intermingle to a certain extent at the surface of contact, and whirls, ripples, and waves will be produced, whose size and shape depend on the respective velocities and directions of these currents.

Now, if the upper current be colder than the lower, as will usually be the case, and if the lower current contain water-vapour near its maximum tension, it is evident that condensation will very likely take place over the crests of these waves. For these portions of the lower current are pushed far up into the colder upper current, and thus have their temperature reduced. To this process we give the title "Interfret" (Fig. 2).

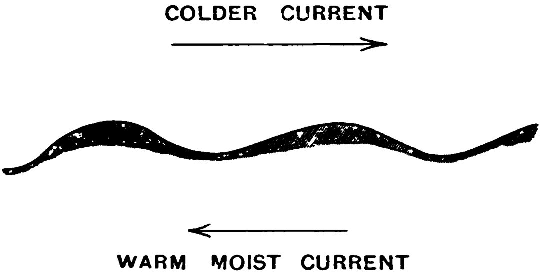


Fig. 2.—Interfret Action producing Cloud.

11. If, however, the lower current be colder than the upper, and the latter is charged with vapour near its maximum tension, we shall have condensation taking place in the hollows of the waves instead of in their crests. To this phenomenon we give the title "Reversed Interfret" (Fig. 3).

We may thus have waves of cloud formed over the sky, either in long parallel rows, in which case the currents are from nearly the same or from nearly opposite points of the compass, or with no actual arrangement in parallel lines, but cut up into small waves, ripples, and vortices, like a "choppy sea." In this latter case we have innumerable patches and flecks of cloud so often seen in fairly quiet weather in summer.

12. There is yet another process of cloud-formation which is distinct from those already mentioned. This process is one belonging almost exclusively to very high and cold strata of air where there is seldom much moisture.

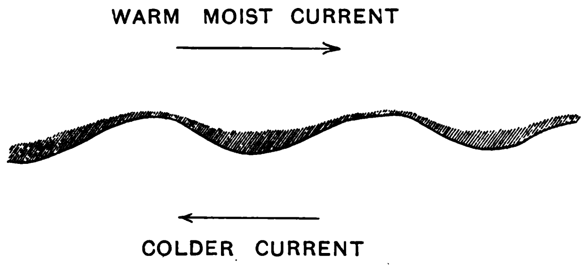


FIG. 3.—REVERSED INTERFRET PRODUCING CLOUD.

If the temperature of the air containing aqueous vapour is very low, and the tension of the vapour is near its maximum for that temperature, a sufficient decrease of temperature will congeal some of the vapour at once into ice. More usually, however, the vapour would first be condensed into water, and then, on decrease of temperature, this would be congealed into ice.

Thus, if water-vapour, from any cause, exists in strata of air of very great altitude and of very low temperature, and has a tension near its maximum for that temperature, and any reduction of temperature takes place (as by Interfret actions), this vapour will be either at once congealed into ice or first condensed into water. In either case, in the rarefied atmosphere in which it exists it will fall by its own weight through strata of air below. The rapidity of descent will further decrease the temperature and ensure congelation into ice. Now, as a general rule, the nearer the falling particles get to the earth, the slower, warmer, and denser are the currents with which they meet. Consequently, the lower the particles descend, the more they lag behind the more rapidly moving particles above, and the higher the temperatures which they experience. They thus form a twisted or curved cloud, which hangs from a point in the sky and disappears again into vapour below. The interpretation of this curve will be treated of in a later chapter. To this method of cloud-formation we give the term "Inclination."

If the reader remembers that ice particles are less dense than water particles, and that their form usually presents a greater surface to the resistance of the air, also that in falling they meet with air of ever-increasing density, he will have no difficulty in understanding how clouds of this kind can exist for great lengths of time at very great altitudes where the pressure and the temperature are very low.

13. A few words may now be said on some other

effects that are produced by aqueous vapour in the atmosphere. Whereas dry air absorbs very little of the heat which passes through it to and from the earth, it is believed that aqueous vapour will arrest a considerable amount of this heat. In any case it is certain, from chromatic and other observations, that a portion of the vapour is often condensed sporadically on dust particles present in the air, for radiation from these particles lowers the temperature of the surrounding air. In this state it acts as a very important screen for the organic life existent upon the globe. The fierce heat of warm climates at periods when the atmosphere is extremely dry is the cause of the severe effects experienced by organic life when this veil is partially withdrawn. On the other hand, the excessively humid atmosphere prevalent in the same or similar latitudes when the tension of aqueous vapour approaches its maximum is favourable to organic life in general, although its enervating and depressing influence happens to be injurious to European man. At very high altitudes the solar rays beating on the mountaineer out of the dark steely sky are almost insufferably hot, and cause severe sunburns on the face and hands, whilst the temperature of the atmosphere is many degrees below zero.

Actual cloud also acts as a screen to solar and terrestrial radiation, as may be seen on a hot summer's day by the cooling effect of the passage or formation of a thick cloud, or by the rise of temperature and disappearance of dew produced on a winter's night by the clouding of the sky.

14. It will be seen, therefore, that the presence of water-vapour aids the condition of "unstable equilibrium," mentioned in § 5, for its rapid increase in amount with decrease of altitude will, by absorption of heat rays, unduly augment the increase of temperature of the air with decrease of elevation.

15. We now come to another important ingredient in our atmosphere. This ingredient, which is in reality an impurity, has hardly received the attention which it deserves. There is no doubt that dust particles in the air not only bear an important relation to organic life on the earth, but also have a very great influence in altering the conditions of the atmosphere above. Researches on the subject have been principally carried out by Professor Aitken, who has devised apparatus by which the number of dust particles in a given portion of air can be counted. He finds that this number depends on the position and altitude of the locality, the direction of the wind, the season of the year, and the hour of the day or night; further, that they are much more sensitive than the air around them to the heating and cooling effects of radiation, so that the temperature of the dust particles, if the temperature is increasing or decreasing, is always respectively greater or less than the temperature of the air.

There are further obscure seasonal variations dependent on velocity of wind and on organic processes taking place on the earth. Aitken found the mean number of dust particles at Kingairloch in the west of Scotland to be about 26,240 per cubic inch (1600 per c.c.), while in London the mean amounted to about 1,640,000 per cubic inch (100,000 per c.c.), and in Paris rather more. Looking at the horary curves of the variations in the quantity of dust on Ben Nevis, we see that all the hours from midnight till 10 A.M. present numbers which are below the diurnal mean, the minimum being about dawn. The curve then rises with great rapidity till 4 P.M., the first part of the rise being somewhat the greatest. It then begins to fall, and continues to do so until 7 P.M., when a considerable check takes place, and the fall is not continued till nearly midnight.

16. Now in all regions of the globe, with but few exceptions, there are diurnal oscillations of atmospheric pressure at the earth's surface. These variations are related to the condensation and evaporation of moisture in the atmosphere, and therefore must be noted in these pages. The exact relationship is not yet fully understood, and forms a subject of essential interest which, when thoroughly worked out, will undoubtedly throw much light on some of the more obscure phenomena of cloud-formation. The diurnal phases may be thus enumerated :—

1. A nocturnal minimum of pressure occurs at early dawn.

2. This is followed by a morning maximum, generally occurring between 8 A.M. and 9 A.M.

3. Pressure then declines to the afternoon minimum, occurring between 2 P.M. and 4 P.M.

4. This is succeeded by an evening maximum, generally occurring between 8 P.M. and 11 P.M.

5. Pressure then decreases gradually to the nocturnal minimum.

These phenomena are much more marked in low than in high latitudes, and near the equator they are so pronounced and so slightly interfered with by the passage of temporary atmospheric disturbances that the hour of the day can frequently be read off by a glance at the barometer.

17. Now Buchan's explanation of these diurnal variations of pressure as caused indirectly by the action of dust particles seems the most plausible. During the night the dust particles lose heat rapidly by radiation into space. They lower the temperature of the surrounding air below the dew-point, and consequently decrease the vapour-tension. This decrease is greatest just before dawn, because then the work of radiation has reached its climax; thus the pressure at the earth's surface is lowest at this time. After the sun has risen vapour-tension is again increased by the evaporation of moisture from the surface of the dust particles; the latter also get superheated by the sun's rays, and help to increase the temperature and the elastic force of the air itself. This double increase is sufficient to affect the barometric column producing the morning maximum at the hour when the lower strata of air are increasing in temperature with the greatest rapidity; for the tendency to lift the whole atmosphere without affecting the pressure at the earth's surface is not

sufficient to overcome the inertia and viscosity of the higher layers, especially as those layers have much fewer dust particles, and are not similarly affected.

Now, as insolation upon the surface of land and water increases, temperature and evaporation also increase, and form strong ascending currents which overcome the resistance of the higher layers mentioned above. Thus pressure again decreases to the afternoon minimum. These descending currents are broken up over land surfaces, and are partially compensated for over each locality by descending currents on all sides of them. It should be observed that dust particles being more numerous and of larger size in the lower strata of the atmosphere than in the higher, the whole operation which results in the afternoon minimum is confined to the lower and middle layers.

After the afternoon minimum caused by the superheating of the lower atmosphere has passed away from the longitudes affected by it, barometric pressure at the earth's surface commences to rise until the evening maximum is attained, which is usually the case after sunset. This maximum may be attributed partly to the overflow of the atmosphere still rising in the west, and partly to descensional currents established in the rear of the upward current.

18. These fluctuations of pressure are, at least over land surfaces, intimately connected with certain definite cloud-formation, especially where there are no very strong horizontal currents. These will be treated of when we come to speak of the cloud-forms

of the globe. It will, however, be seen here that the morning and evening maxima will generally coincide with the least amount of cloud, because in the first the increase of vapour-tension is not rapid enough to enable the resistance of the upper strata to be overcome by an ascensional current, and because in the second case descending currents exist which cause evaporation of water particles. The afternoon minimum, however, frequently coincides, over those land surfaces which are not extremely arid, with the maximum formation of "Inversion" clouds, and therefore of precipitation.

It may also be mentioned that wherever there are, owing to geographical position, upper currents of considerable velocity, unaffected by the heating of the lower layers of air, the rapid nocturnal cooling of the middle and upper strata tends to produce high night cloud of Inclination and Interfret types. In such cases we frequently observe the greatest amount of cloud and also of precipitation in the hours of the night. This is particularly the case upon and in the neighbourhood of high mountains, the nocturnal radiation from which tends to lower the temperature of the surrounding atmosphere.

CHAPTER II

CLASSIFICATION, NOMENCLATURE, AND DESCRIPTION OF CLOUDS

19. THE task attempted in the following chapter possesses certain intrinsic difficulties which must be immediately faced. In the first place, the objects of our research being for the most part inaccessible, we rely to some extent upon theory, while our ends are in the main practical. In the second place, it must be distinctly understood that many types of cloud merge imperceptibly into one another. The last, but not least, of the obstacles which beset us lies in already existing nomenclatures, not only differing from one another, but also running counter here and there to those broad distinctions of physical structure which observers should take as their basis of classification. It seems undesirable to sweep away all existing nomenclature, not only because many of the divisions hitherto adopted appear to coincide with those differences of structure which in their results have presented themselves to the eye of every good observer, but because we cannot expect men to abandon all the associations connected with those characteristics of sky to which certain of the best cloud-names have been given. To

the aim of making the weather-watcher as competent as possible in the identification of cloud structures, which is at present the principal object to be attained, a certain portion of the logic of nomenclature has with reluctance to be sacrificed. Thus, in compound names the termination of the affix sometimes signifies that the whole name denotes an actually compound cloud, sometimes that it denotes the primary kind of cloud, while the suffix expresses some important modification of structure capable of being readily identified.

20. In Table I., to every scientific name there is appended an English title in the second column, in the third an abbreviation, and in the fourth a symbol, which will be found of utility in charts, and for special purposes.

In Table II. certain sub-species or varieties are similarly treated.

One of the objections offered to this classification is that it is too simple. Another, more repeatedly urged, is that it is too complex, and that what is most needed, if a science of clouds is to be popularised, is the cutting down of the number of names, and the general simplification of nomenclature. Few men, it is contended, will be induced so to take up the study of cloudland as to care to learn what any particular cloud looked at should be named. Some authorities on this subject, to whom I am indebted for valuable observations, would reduce the divisions of clouds to three, or even two. By doing this we might greatly amplify the number of observers; but the mass of observations so collated would be of relatively small utility. A definite system of recording observations by officers of the Royal Navy, or of our Merchant Ships, and by travellers in different portions of the globe, would be undoubtedly of some use in acquainting us more closely with the distribution of fish, birds, and mammals; but a thousand years of such observations would not add so much to our knowledge of the fauna of the globe as a single scientific voyage like that of the *Beagle* or the *Challenger*.

To some of our well-known painters, over whose real landscapes, while they painted them, many an exquisite typical cloud-form must have rested, no distinction of these cloud-forms has presented itself. These painters tell us plainly that a cloud is nothing but a mass of water droplets, perpetually changing its form without any law deserving study; and their pictures would certainly themselves give us this idea:

> Do you see yonder cloud that's almost in shape of a camel?
> By the Mass, and 'tis like a camel indeed.
> Methinks 'tis like a weasel.
> 'Tis backed like a weasel.
> Or, like a whale?
> Very like a whale.

Had these artists, who happily do not represent the whole class of our landscape painters, realised that in every part of every painting the brightest contrasts and the softest harmonies can only be obtained from a study of real nature in her physical aspect, more beautiful, because more true, would their art have been. But if the painter destroys the atmospheric effects of his painting by the apparition of rain falling from a thin strip of interfret cloud, or from a cumulus of about a thousand feet in height, or (what is no worse) by a rainbow with inverted colours, he at least only reflects what has been the tendency of the majority of the ordinary public, which seems to have disproved the accuracy of what was once taken to be the derivation of the Greek title for man by an inability to look above the horizon.

The old comedian says something like this, with vagueness not unsuitable to the objects of our study:

> We, ever-fleeting clouds,—
> Seem fairies,—raised our water-life
> Of light, from out old deep-bassed sea,
> High on the heads of lofty hills
> Tree-maiden-haired, and there
> Gaze on the watch-peaks far,
> And on the holy earth that feeds
> The fruits, and rushings of the true-god streams,
> And the voiced main, low-thundered ; for
> The untoiled eye of air is beaming
> In glistening gleams.
> Yet shaking loose the showery mists
> Of deathless dream we witness claim
> Earth, to far-spying sight.

21. Leaving here effusions of the world's boyhood, we anticipate that the power of distinguishing the great divisions of clouds will lead to the recognition of important varieties; that among these the reader will appreciate some of the most beautiful as well as the most delicate of natural phenomena; and that he will be able to assist the agriculturist in many matters

dependent on weather, to help others as well as himself in deciding on the date of a pleasant voyage, and to determine the important question whether or not he shall carry with him an umbrella for utility. More than all, engaged in a fascinating study, he will finally be able to add to our knowledge, and to aid towards the perfection of a system which is at present necessarily somewhat tentative and provisional.

22. It is unfortunate that in this tentative system we cannot adopt as the fundamental basis of classification the division into rain, hail, and snow *stadia* which has been principally due to the very able work of Von Bezold. Observations have not yet been carried far enough to render it possible to accommodate classification to such a basis without sacrificing those distinctions which make improvement in observation feasible. It is equally a matter of regret that we cannot at present admit *mixture* of masses of atmosphere of varying humidities and temperatures as constituting by itself a division of cloud - forms. Fogs primarily due to loss of heat by radiation are dependent, to some extent, on the commingling of atmospheric currents, such as those which roll down the sides of hills into the colder valleys at night; and a rather similar remark might be made in reference to the growth of clouds at a considerable and at a great elevation. Further, it is undeniable that mixture plays an important part in the formation of the clouds which are produced between extensive currents moving with different velocities. Nevertheless, it is needful patiently to await further study before we

can decide in what precise degree condensation is due to the commingling of air-currents as distinguished from other causes. Theory is the balloon by the buoyancy of which the car of observation rises and progresses, but rise and progress are impossible if the ropes are snapped at the start.

TABLE I

NUBES: CLOUDS

I

CLOUDS OF RADIATION

Scientific Name.	English Name.	Abbreviation.	Symbol.
Nebula	Fog	*Neb.*	≣
Nebula Pulverea	Dust Fog	*Neb. Pulv.*	⁙

II

CLOUDS OF INTERFRET

Nubes Informis	Scud	*N. Inf.*	= =
Stratus Quietus	Quiet Cloud	*Str. Qui.*	═
Stratus Lenticularis	Lenticular Cloud	*Str. Lent.*	◇
Stratus Maculosus	Mackerel Cloud	*Str. Mac.*	⌶⌶
Stratus Castellatus	Turret Cloud	*Str. Cast.*	∩∩

III

CLOUDS OF INVERSION

Simple	*Cumulo-rudimentum*	Rudiment	*Cum.-rud.*	O
	Cumulus	Heap Cloud	*Cum.*	⌓
Composite	*Cumulo-stratus*	Anvil Cloud	*Cum.-str.*	⊼
	Cumulo-nimbus	Shower Cloud	*Cum.-nimb.*	Ѫ
	Nimbus	Rainfall Cloud	*Nimb.*	⧣

IV

CLOUDS OF INCLINATION

Nubes Fulgens	Luminous Cloud	*N. Fulg.*	⸝
Cirrus	Curl Cloud	*Cir.*	)

Scientific Name.	English Name.	Abbreviation.	Symbol.
Cirro-filum	Gossamer Cloud	*Cir.-fil.*	
Cirro-velum	Veil Cloud	*Cir.-vel.*	
Cirro-macula	Speckle Cloud	*Cir.-mac.*	

23. To the above list of names the following varieties are added. These, of interest in themselves, throwing light on physical processes to which cloud-forms are related, and also typical of special states of weather in different portions of the globe, are in respect of importance very dissimilar to one another.

TABLE II

I

CLOUDS OF RADIATION

Scientific Name.	English Name.	Abbreviation.	Symbol.
Nebula Stillans	Wet Fog	*Neb. Stil.*	

II

CLOUDS OF INTERFRET

Stratus Præcipitans	Plane Shower	*Str. Præc.*	

III

CLOUDS OF INVERSION

Cumulo-stratus Mammatus	Tubercled Anvil Cloud	*Cum.-str. Mam.*	
Cumulo-nimbus Grandineus	Hail Shower	*Cum.-nimb. Grand.*	
Cumulo-nimbus Nivosus	Snow Shower	*Cum.-nimb. Niv.*	
Cumulo-nimbus Mammatus	Festooned Shower Cloud	*Cum.-nimb. Mam.*	
Nimbus Grandineus	Hail-fall	*Nimb. Grand.*	
Nimbus Nivosus	Snow-fall	*Nimb. Niv.*	

IV

CLOUDS OF INCLINATION

Cirro-velum Mammatum	Draped Veil Cloud	*Cir.-vel. Mam.*	

24. The following brief sketch of the broad distinctions between the genera of clouds embraced in this classification may be of use.

Roughly regarded, a fog might be said to be a cloud viewed from within and a cloud to be a fog viewed from without. The clouds which occur on hill-sides and on elevated coast-lines are frequently termed fogs, and cannot always, owing to their persistence, be described by the observer as belonging to any particular variety. Such clouds should simply be denominated "nubes," "n," or "clouds," to avoid the confusion which arises from fruitless attempts at distinction, although there are many clouds within which the observer is temporarily placed which are of a sufficiently transitory character to enable him to give them their right denomination. Nebula differs from the clouds of Interfret principally in this respect, that, not being due to the interaction of currents of varying velocities or direction, it is not structurally composed of small cloudlets, whether separate or more or less welded together. Its lower surface also usually rests upon the floor of the atmosphere, although, as we shall presently see, it may be slightly raised above that floor. Generally speaking, it grows by upward accretion, for the diminution of temperature due to the radiation of heat into space, which begins near the earth's surface, presently, under favourable circumstances, takes place in the upper surface of the fog, and vapour is condensed or congealed at an increasing elevation above the earth. Light being radiated in the same manner as heat, a fog viewed from above in the daytime appears bright, while the earth where there is no fog is relatively dark. The evaporation and disappearance of a fog take place, in most instances, in the reverse order, the upper surface being converted into vapour first, and the lower surface last, although there are certain marked exceptions to this rule.

Clouds of the Interfret types are far more difficult than clouds of any other genus to distinguish from one another, and they also exist at much more variable altitudes. This is particularly the case with special kinds, and not least of all with what we denominate *Stratus Maculosus*, which is a cloud of moderate interfret, which may occur at rather low or at very considerable elevations, and which may consist of nubecules of small or of large dimensions. The *Stratus Quietus*, which occupies the second place in this division, approximates most of all in character to the clouds of radiation, while the opposite extreme is found in *Stratus Castellatus*, which is essentially dependent for its existence on the close proximity of currents of very varying velocities. Although the physical conditions necessary for the formation of the last-mentioned variety are too marked to admit of hesitation in assigning it to the second genus of clouds, yet the Turret Cloud, in its ulterior development, rapidly becomes a cloud of Inversion, and frequently spreads into one of the most interesting and magnificent of the *Cumulo-nimbi*. It is for this reason that it is placed last in the list of the clouds of Interfret.

With regard to the clouds of Inversion little need in this chapter be said, except that the distinction between *Cumulo-stratus* and *Cumulo-nimbus,* long ago insisted upon by the author, possesses an importance, especially in attempts to form forecasts of weather, which must not be underrated.

The clouds of Inclination are, with few exceptions, easily recognisable to most observers, though I may be permitted to mention here that I have known an authority of no mean repute in this branch of study to be totally unable to distinguish between *Cirrus* and smoke rising from chimneys. Of *N. Fulgens* something will be said in a following chapter. The principal exception alluded to is that of *Cirro-macula,* in the production of which the phenomena of interfret unquestionably play an important part, and which has been consequently treated as a kind of mackerel cloud by nearly all observers, who have comprised *Stratus-Maculosus* and *Cirro-macula* generally under the single title of *Cirro-cumulus.* That title has to be rejected, because in any case neither variety belongs essentially to the genus of the clouds of Inversion. It is with the aim of distinguishing clouds belonging to the upper currents from those belonging to the middle currents of the atmosphere that here the logic of nomenclature is sacrificed.

With regard to the varieties of cloud entered in Table II., it is sufficient to mention here that they differ from one another greatly in importance, and further, that the three varieties of festooned cloud are intimately related to one another in reference to the causes which produce them, and essentially distinct in reference to the nature of the weather which precedes and follows their occurrence.

25. The following table shows the altitudes occupied by the different varieties of cloud. These altitudes do not precisely correspond with those determined by previous authorities. For example, we are obliged to offer an apology to a very great student of this subject, Dr. Vettin, in being forced to regard many clouds as having greater altitudes than those determined in his valuable investigations. And with regard to the level of the summit of the highest shower clouds, an altitude is here given which is in excess of that adopted by the majority of previous writers. I may be allowed to say that the altitudes in the table are obtained from the work of a lifetime, and are not stated without careful consideration of all that has been, up to the present date, published on this subject. Much valuable work has been done by Hildebrandsson, Ekholm, Hägstrom, Clayton, and many others in this branch of investigation. The employment of theodolites, telephones, etc., is very interesting labour. A description of instruments is avoided here.

TABLE III

APPROXIMATE AVERAGE ALTITUDES ABOVE MEAN SEA-LEVEL

Variety.		English feet.	Metres.	Remarks.
Nebula		50	15	Variation from mean small, depending on locality.
,, Pulverea		3,000?	918?	Variation probably great.
Nubes Informis		1,400	428	Does not vary much.
Stratus Quietus		3,100	948	Variation from mean small.
,, Lenticularis		15,000	4,590	,, ,, ,, very great.
,, Maculosus		9,000	2,754	,, ,, ,, great.
,, Castellatus		20,000	6,120	,, ,, ,, moderate.
Cumulo-rudimentum		1,500	458	,, ,, ,, small.
Cumulus	base	4,000	1,224	,, ,, ,, moderate.
	summit	7,500	2,295	,, ,, ,, great.
Cumulo-stratus	base	4,000	1,224	Does not vary much.
	summit	7,000	2,142	
Cumulo-nimbus	base	4,000	1,224	Varies very greatly; the base sometimes attains an altitude of 25,000 ft. and the summit an altitude of nearly 50,000 ft.
	summit	10,000	3,060	
Nimbus	base	1,400	428	Varies greatly, but not so much as the previous cloud.
	summit	20,000	6,120	
Nubes Fulgens		300,000?	91,800?	Altitudes uncertain, but exceedingly great.
Cirrus		25,000	7,650	Varies very greatly between 5000 and 42,000 ft.
Cirro-filum		30,000	9,180	Varies very greatly between 10,000 and 45,000 ft.
Cirro-velum		26,000	7,956	Varies greatly between 10,000 and 40,000 ft.
Cirro-macula		23,000	7,038	Variation from mean great, but not so great as the previous cloud.

In estimating the amount of cloud the framework of Palowsk is of use. But in whatever way we choose to determine the amount of cloud, it is rather to the appearance, to the variety, to the utility of cloud observations in the forecast of weather that attention is in these pages devoted.

CHAPTER III

CHARACTERS AND CONTRASTS—CLOUDS OF RADIATION

Nebula

26. THE spherules of water which constitute nebula vary greatly in diameter, approximately between the limits of ·01 inch and ·0001 inch, and are measurable both mechanically and by the chromatic method. In perfectly tranquil air these particles descend to the earth's surface with a velocity chiefly dependent on the square root of their diameters and the pressure and temperature of the air. At a pressure of 29·92 inches (760 mm.), a water particle, regarded as a perfect sphere, having a diameter of ·0001 inch (·025 mm.), will, at the temperature of the melting-point of ice, have a terminal velocity of descent of 1½ miles per hour (·67 m.p.s.). But perfect tranquillity does not exist in nature, and a very slight horizontal movement is sufficient to arrest, according to a well-known mechanical law, the downward movement of water spherules.

27. The ground fog characteristic of land surfaces in nocturnal and winter conditions is most essentially, to adopt a name borrowed in the first place from

Herschel, the cloud of "radiation." Interfusion, or commixture, of the adjacent laminæ of the atmosphere cannot play a very important part in its production. For, in the first place, land fog is often formed over surfaces which are very nearly level, and, in the second place, as is well known to any observer in the country, it is only developed, or it is first developed, over a portion of the earth's surface which can be experimentally shown to be, from one cause or another, of lower temperature than adjacent portions. For instance, in a winter night in the higher latitudes nebula frequently appears over a piece of pasture land before it is produced over arable ground in the vicinity, irrespectively of elevation. Herbage not only keeps the surface of the earth beneath it moist, and supplies much moisture by night as well as by day to the contiguous atmosphere, but radiates heat very freely into space. The air which is in actual contact with herbage precipitates part of its vapour in the form of dew or of hoar-frost; but the layers of atmosphere immediately above this, having their temperature lowered to the dew-point, deposit moisture on the dust particles, which are themselves losing heat by radiation. This process may quietly continue under favourable circumstances up to the coldest period of a winter's night, the hour of the occurrence of which principally depends upon latitude. Under the same circumstances fog begins to be reconverted into vapour soon after insolation begins. Hence we have our misty mornings, followed by bright afternoons, characteristic of settled weather in the colder months of the year in such climates as that of the British Isles. Over extensive plateaux ground fogs are less noticeable, because the surface of the earth is drier and irrigation generally less abundant; and over wide plains in the central portions of large continents they are especially rare, simply because the atmosphere here contains but little of the vapour supplied from oceanic surfaces. Unfavourable conditions may be brought about in several ways. The upward extension of nebula may be so great as to check radiation; clouding of the upper sky may have the same effect; a change in the distribution of atmospheric pressures near the earth's surface may occur, producing motion of the air sufficient to disperse the fog at an hour when it would otherwise continue; just as the continuance or increase of nebula at an unusual hour may be effected either by an increase of terrestrial radiation, due to incidental causes, or to results of artificial increase of dust particles through the augmentation of imperfect combustion during the daytime in large towns. As an example of the first process, it may be mentioned that I have seen a fog of great density, several feet in vertical thickness, suddenly produced on a hot afternoon in August by a thunderstorm, which left the surface of the ground covered with hail two inches deep. In this case, of course, the absorption of heat in the partial melting of ice caused vapour in immediate contact with the ice to be condensed. Nebula must not, however, be regarded as in all cases a very local phenomenon, or again, as restricted to periods when the atmosphere near its floor is calm.

In the higher latitudes the extent of a fog largely depends upon the extent and intensity of one of those systems of non-periodic atmospheric circulation within which the pressure of the atmosphere near the earth's surface is relatively great. In these there are in winter none of those upward movements which promote the dispersion of fog; and, further, it is obvious that an increase of atmospheric pressure must, to a slight extent, promote the suspension both of the particles of dust, and of the fog which accompanies it. Near the exterior of these systems, where there is a decided but somewhat equable movement of air, which has recently traversed some portion of a water surface, the favourable effects of great atmospheric pressure more than counterbalance the unfavourable effects of disturbing movement, and fog drifts over the earth's surface. Here terrestrial radiation plays a rather less important part, and the interfusion of adjacent portions of air, differing in temperature and humidity, begins to assert itself.

28. This leads us to the consideration of those fogs which are essentially maritime, and are in this respect dissimilar to the fogs already described. In some parts of the globe the contrast is obvious in reference to the annual maxima and minima of the occurrences of nebula. To take a well-known example: Over the English Channel fog is most prevalent in the month of June, which very nearly coincides with the time of the annual minimum of fog over the inland parts of Western Europe. A local observation, in this connection, may help us to interpret the cause of sea

fogs in many parts of the globe. Records of sea temperature, taken in the shallow bay of St. Aubin, Jersey, by the late Mr. Vibert, a friend of the writer, show that here, although the sea feels the effects of insolation earlier in the summer than in the deeper parts of the Channel, the mean temperature of the water is at this season lower than the mean temperature of the air above it. It will be indicated hereafter that non-periodic systems of high barometric pressure are characterised by warm weather in summer for the same reasons which tend to make them areas of cold weather in winter. When one of these systems lies over France, the south-westerly and westerly winds of its northern portion pass over the English Channel, having become nearly saturated, quite saturated, or supersaturated in their passage over some portion of the North Atlantic. The air immediately contiguous to the waters of the Channel is kept cool by the relatively low temperature of the latter; and a moist current moving over it, and partially commingled with it, has its vapour condensed into fog. Nebula formed in this way obviously cannot penetrate into inland localities, where (only for short periods in our own fickle climate) there is a concomitant or subsequent reign of brilliant summer weather.

29. It is obvious, then, that sea fogs are liable to occur whenever and wherever the surface water of the sea is of much lower temperature than that of land or of other surface water in the vicinity, supposing climatic conditions to be such that interfusion is capable of producing nebula, and supposing special atmospheric

conditions to result in the necessary movements of the air. The climatic conditions of the lower latitudes, where the surface water rarely falls much below the mean temperature of the air, and where this air, though very humid, is seldom saturated, are evidently adverse to the formation of fog; and, consequently, between the tropics, maritime fogs are of rare occurrence. On the other hand, over those regions in higher latitudes in which adjacent surface temperatures differ greatly, in which a very slight diminution of temperature leads to the attainment of the dew-point, and in which, finally, the distribution of atmospheric pressures favours the mixture of surface winds of different temperatures, all conditions are favourable to the production of fog. A too-well-known instance of the concurrence of these conditions is found off the Bank of Newfoundland, where cold ocean currents from the Arctic regions are in very close contact with warm currents from within the Tropics.

30. When frost occurs in accompaniment with fog, certain effects are produced which are worthy of attention. The conversion of water particles into ice as they come in contact with the earth frequently keeps the temperature of the lowest layer of air so high that a majority of the particles suspended in it are restored to the vapour form. In a frosty fog I have, by stooping, seen animals in a field when these were invisible while the spectator adopted the erect attitude. The formation of rime, which confers such an exquisite beauty on many a winter scene, is a result of a nebula occurring during frost. If the fog

particles were themselves frozen, nothing but a little ice dust would be accumulated upon the blades of grass, or on the exposed surfaces of the limbs of trees. Instead of this we find large crystals, which grow by slow accretion (on the windward side, if there is motion of the air), upon the solid surfaces, until these crystals are sometimes more than one inch in length. In the continental forests, during winter weather, rime is occasionally accumulated on the trees to such an extent as to cause much injury to the timber, and this occasionally occurs even in England. When the fog is restored to the vapour form by the warmth of the sun's rays, or by a mild current of air, the crystals, becoming partially liquefied, are detached from the twigs of the trees, and vegetation is again stripped of its spangled armour. It is a mistake to suppose that frosty fogs are commonly frozen. Nevertheless, in high latitudes, under favourable conditions, the particles become spicules of ice, and such fogs, as Nordenskjöld found to his cost, are extremely opaque and disagreeable. Even in England ice fogs may occasionally occur, and something of the kind is mentioned by White in his *History of Selborne*. But particles of ice drifted from trees are liable to be mistaken for crystals formed in the atmosphere. I am of opinion that ice fog is not yet sufficiently investigated to merit the title of *Nebula Glacialis*.

Nebula Stillans

31. On the other hand, when the particles of fog are large enough to be precipitated rather rapidly to the earth, and yet not large enough to be called rain, this phenomenon seems to deserve a separate title among the minor varieties, as *Nebula Stillans,* or wet fog, for it is distinctive of particular types of weather. In some parts of the world observers are induced by habit to regard as fog what in other parts would be distinctly considered rain. Thus a "Scotch mist" is more than a mist to those who are not inured to it.

Nebula Pulverea

32. We now come to the important consideration of the part played by dust particles in the production of fog. That subject has been dealt with in a general way in §§ 15-18. It is one of the inconveniences of imperfect civilisation that the products of imperfect combustion greatly augment the density and change the character of the fogs of large towns. It must, by the way, be remembered that a good deal of vapour is given off in the burning of bituminous coal. It was calculated some years ago that from the coal daily consumed in London in winter 667,460 cubic feet of steam, at the temperature of the melting-point of ice, pass into the atmosphere. This moisture, when there is little horizontal movement of the air, slightly promotes the condensation of previously existing vapour over a large city. But the great

cause of the persistence and opacity of town fog is due to the presence of carbon, which determines the conversion of vapour into fog particles. It might seem convenient to classify fogs of this description under a special title, but this cannot well be done. In the first place, it is impossible to determine the exact limits either of character or of locality belonging to these fogs. A second and minor consideration may be taken into account, which is this: It is possibly not over sanguine to anticipate that the town fog is a temporary evil. It is an evil, by the way, which is specially adverse to the study of clouds, for it is frequently difficult, and occasionally impossible, for the inhabitant of a large town to distinguish varieties of cloud which in the open country are quite unmistakable. The name *Nebula Pulverea* is given to a class of fogs belonging to the domain of nature rather than of art. This class is truly hazy in its limitations. Near, or on the summits of high mountains, a layer of haze is frequently visible, which possesses no great vertical thickness, which has a rusty colour in the daytime, and which is not noticed by an observer at the base of the mountain. That this layer of haze consists in some places of iron dust, as on the Peak of Teneriffe, has been shown to be probable by the observations of Dr. Marcet and of other investigators. But the most important kind of dust fog with which we are concerned in these pages occupies a comparatively low level in the atmosphere. In some parts of the globe *Nebula Pulverea* is occasionally so thick as almost totally to obscure rays of sunlight. This occurs, for example, in Abyssinia, and has led to the tradition that the account of the plague of darkness in Egypt is an account of an unusual dust fog. Even in the higher latitudes of the globe the occurrence of layers of dust fog is common. When noticed, as is most usual, in the later hours of the afternoon, when the diurnal force of the wind has accomplished its maximum of work in drifting particles from the earth's surface, and when radiation into space has begun its own work in so cooling these particles as to render them visible through a slight deposit of water upon their surfaces, the appearance of lines of thin dust fog parallel to the horizon is frequently of valuable assistance to us in prognosticating the formation of more or less *Stratus Quietus* in the coming nocturnal hours. It requires a little experience to distinguish these lines from those of *Cirro-filum.* Colour assists us in making the distinction. Viewed in transmitted light they are of a faint orange yellow tint; in reflected light —and it is in the East that we look for them most especially—their colour is neither white, like *Cirro-filum,* nor neutral, like beds of actual *Stratus Quietus,* but of a dull rusty red. Form helps us even more. They everywhere appear nearly parallel with the horizon, and do not exhibit the converging and diverging effects due to perspective, which characterise the higher clouds.

33. A good deal of haze occurs under varying conditions in various parts of the globe. Thus the

blue sky is much obscured in the damp weather of low latitudes by sporadic condensation. In the higher latitudes haziness of the atmosphere is often observed during damp weather, with winds blowing off ocean surfaces; while, on the other hand, precipitation frequently clears the atmosphere of dust particles to a marked extent, and extreme transparency of the atmosphere is in some places regarded as an indication of coming rain. A sporadic haze, principally due to the existence of dust in the air, often accompanies special systems of wind circulation, as, for instance, the north-east winds of Western Europe.

This kind of haze, red in transmitted, and blue-grey in reflected light, is often called "blight," although it does not in reality consist of organic particles. We occasionally see in many parts of the globe a haze really produced by aphides, and this is not uncommon in fine September weather in England, and can easily be distinguished by its colouring. But this phenomenon hardly belongs to the subject of these pages, any more than a pollen cloud or a cloud of locusts.

CHAPTER IV

CLOUDS OF INTERFRET

Nubes Informis

34. FIRST in the list of the clouds of Interfret is inserted a cloud easy of recognition, and often readily accessible, but about the most suitable position of which, in our classification, doubt may reasonably be entertained. The low drifting cloud which we term *Nubes Informis*, and to which the English name "scud" is familiarly applied, cannot fairly be regarded as a cloud of Radiation; neither is it strictly one of Inversion. It is a cloud of movement, and a cloud which scarcely exists where the velocity of movement is uniform in contiguous layers of air. But it possesses nothing of that tendency to definite structure of nubecules, compact or separate, which essentially belongs to the majority of the clouds of Interfret. Occasionally it merges into *Nebula* on the one hand, or into *Cumulo-rudimentum* on the other. But, generally speaking, it is distinguishable from either of these. Sometimes it coexists with *Cumulo-nimbus*, and with *Nimbus*, forming the basal portion of the latter important variety of cloud. At other

times it is solitary, or is incidentally produced beneath the higher clouds of Interfret, or of the clouds of Inclination. In the former instances it will have to be referred to again presently, being associated with special types of weather. But, on the whole, it has received from different authors rather more attention than I think it to deserve. And, in any case, it is so well known that little more need be said about it in the present section.

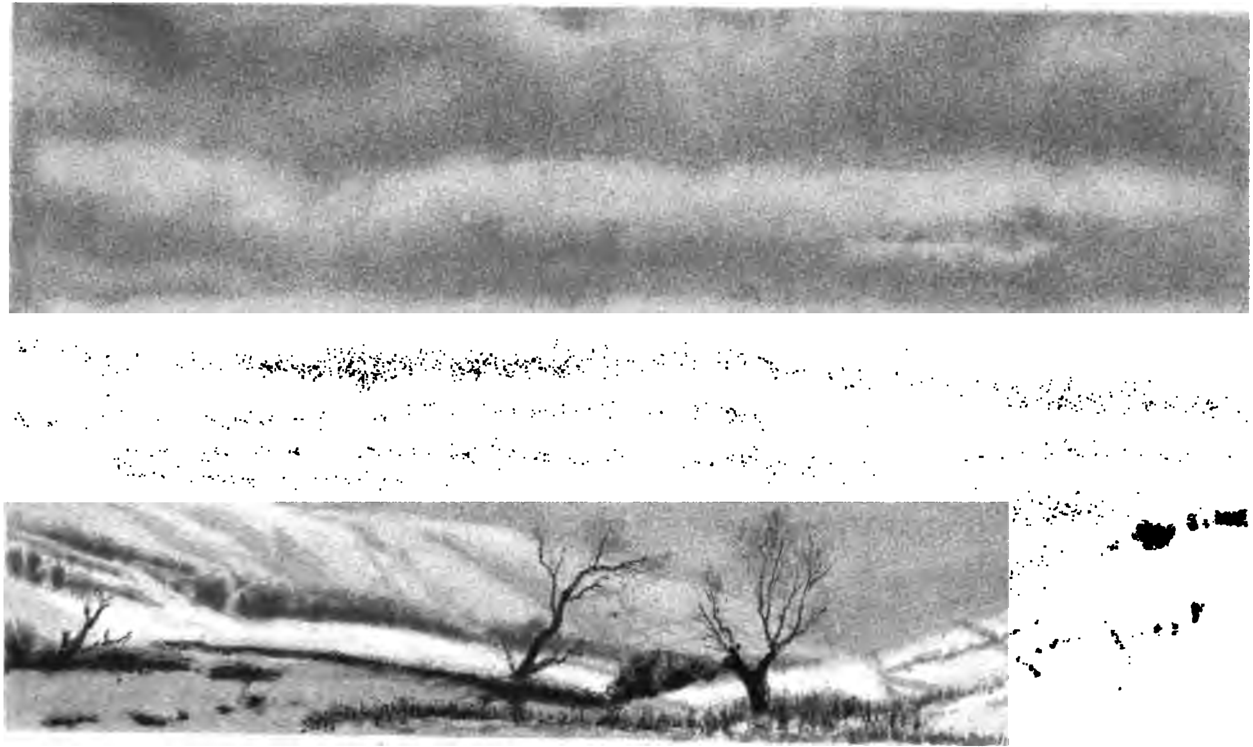
About the peaks of mountains, and in the passes among crags, rather amorphous clouds form tattered banners, the production of which is well understood, and the sight of which is very familiar to travellers. These streamers of cloud adapt themselves to the forms of the rocks and peaks which give them birth, and merit no further notice here.

Stratus Quietus

35. We now come to a much more important variety, the *Stratus Quietus* of our nomenclature. It has already been stated that this variety approximates most closely in structure to the clouds of Radiation, and unquestionably radiation plays an important part in its production. Nevertheless, this cloud of tranquil weather is not very prevalent over those parts of the globe and at those seasons of the year in which terrestrial radiation is most active, viz. in the interior of the continents of the higher latitudes in winter.

Stratus Quietus requires for its development two interdependent agencies, a slight and rather extensive downward motion of the atmosphere and a slow horizontal movement of air over the upper surface of the cloud. The first agency may be said to determine the possibility of the cloud's formation, the second the degrees and characters of its structural arrangement. In reference to the first it should be stated that the occurrence of the cloud marks the tropical belts of high barometric pressure, the shifting and well-defined areas termed anticyclones, the winter season, and the nocturnal hours. In reference to the second, it is to be remarked that amount of interfriction determines whether the cloud is an almost uniform sheet or presents a broken and knotted appearance due to the separation and agglutination of nubecules. When nearly uniform the cloud slightly resembles *Nebula*. Nowhere, when the velocities of superimposed currents differ most, does its structural arrangement rise to the complete symmetry of *Stratus Castellatus*, the wondrous architecture of *Cumulus* and *Cumulo-Nimbus*, or to the silken embroidery of the cirriforms.

26. The mean altitude of *Stratus Quietus* is about 3100 feet (945 m.) above mean sea-level, as given in Table III, and the variation between the extreme altitudes is not very great; neither is the difference between the level of the cloud above the tropical calm belts and above the transitory systems of atmospheric circulation very considerable. The vertical thickness of the cloud is small, on the average only 760 feet (232 m.), and the cloud obstructs much light, the nubecules being dense and abundant.



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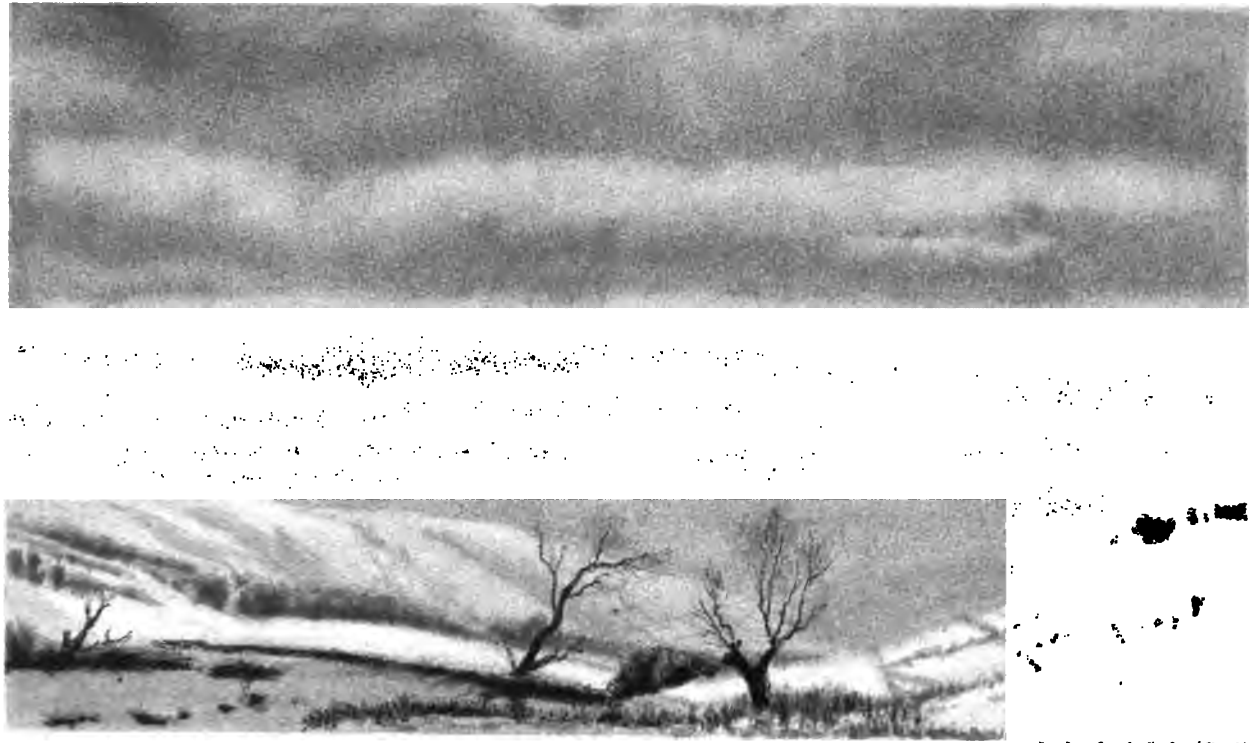
STRATUS QUIETUS

extensive downward motion of the atmosphere, and a slow horizontal movement of air over the upper surface of the cloud. The first agency may be said to determine the possibility of the cloud's formation, the second, the degrees and characters of its structural arrangement. In reference to the first it should be stated that the occurrence of the cloud marks the tropical belts of high barometric pressure, the shifting and non-periodic areas termed anticyclones, the winter season, and the nocturnal hours. In reference to the second it is to be remarked that amount of interfret determines whether the cloud be an almost uniform sheet or present a broken and knotted appearance due to the separation and agglutination of nubecules. When nearly uniform the cloud slightly resembles *Nebula.* Nowhere, when the velocities of superimposed currents differ most, does its structural arrangement rise to the complex symmetry of *Stratus Castellatus,* the ponderous architecture of *Cumulus* and *Cumulo-nimbus,* or to the silken embroidery of the cirriforms.

36. The mean altitude of *Stratus Quietus* is about 3100 feet (945 m.) above mean sea-level, as given in Table III., and the variation between the extreme altitudes is not very great; neither is the difference between the level of the cloud above the tropical calm belts and above the transitory systems of atmospheric circulation very considerable. The vertical thickness of the cloud is small, on the average only 760 feet (231 m.), yet the cloud obstructs much light, the particles being coarse and abundant.



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STRATUS QUIETUS

Illuminated by the sun, the cloud reflects to the earth impure orange and red orange. In shadow it is seen of an impure neutral or of a bluish-gray tint. Wherever there are large gaps in the quiet cloud at a distance from the zenith, if the atmosphere below is devoid of much haze, these colours, viewed nearly opposite to the sun's position, are often very distinctly marked, and the slightly rugged upper surface of the patches, whose irregularity is due to the process of interfret, is plainly visible. Seen from above in the beautiful atmosphere most commonly prevailing over a canopy of this cloud, the upper surface, which here reflects much sunlight, is seen to be composed of innumerable sloping ridges of no great height; and it is over and among the corries of the cloud that the current of air to which their figuration is due travels with slight or with very moderate velocity, the vertical component of which current is observationally almost inappreciable.

When *Stratus Quietus* occupies a layer of air near the lowest level at which it usually exists (Table III.), and when the portions of cloud are not compactly welded together, it presents an appearance similar to that represented in Plate II. When, on the other hand, the cloud is near its highest elevation, when it is distributed in a rather compact canopy, either totally unbroken, or having small apertures visible only near the zenith, the under surface of the cloud-bank exhibits irregular clusters and agglomerations. But, in any case, since the cloud is not arranged in real strips or bands, the apparent belts of deeply shadowed and of more illuminated portions appear to the eye nearly parallel with the horizon. An exception worthy of notice occurs when the exterior edge of a bank of this cloud approaches the observer. Such an edge is sometimes approximately rectilinear, and therefore in perspective appears curved. This is notably the case when in the higher latitudes the outside edge of a sheet of this cloud approaches the observer on a moonlight night, and this is an apparent confirmation of the popular belief that moonlight clears the sky of cloud.

37. Very important are the connections between the occurrence of this cloud and special types of weather, and somewhat strange is the fact that little attention has been given to these. Part of this subject will be dealt with when we speak of the cloud-forms of the "Anticyclonic" systems, § 166. Here we may observe that even in interspaces between cyclonic disturbances, and, in short, wherever there is any downward movement of the air, there is a tendency to the formation of this cloud; further, that the gradual or sudden disappearance of the cloud after a long spell of its occurrence in the higher latitudes deserves the most careful attention on the part of the local observer, since this disappearance is the forerunner of a change from settled to unsettled weather, and of a change from calm to windy conditions. It is also worthy of remark that the rather uncommon occurrence of this cloud in the summer of higher latitudes in concurrence with clouds of Inclination at a great altitude above it is, for reasons which will appear

evident when we deal with the clouds of Inclination, a harbinger of rainy weather, and should be noted with care by the agriculturist. Finally, this form of cloud is far more characteristic of certain years than of others, not only in the higher, but also in the lower latitudes; and in the higher latitudes its occurrence in unusual frequency is a concomitant of cold summers.

Stratus Lenticularis

38. This is nowhere an abundant cloud, though common at particular times of the year over certain parts of the globe, *e.g.* over the northern part of the tropical calms of the North Atlantic; and it is a variety which has received scant courtesy. When a patch of cloud has an approximately circular periphery, and a somewhat greater vertical thickness at or near its centre than at its edge, towards which it shelves off, being, in fact, a flat spheroid, its largest diameter lying parallel to the earth's surface, we call the cloud Lenticular, because it approaches to the form of a double-convex lens, originally supposed to resemble a lentil in shape. The form is quite unmistakable when the cloud is seen near the horizon (Plate V.). When it is near the zenith we recognise at once that it is composed of nubecules, which appear to be most closely welded together in the central portion; and we consequently classify the cloud among those of Interfret.

The range of altitude of this cloud is very great indeed, as indicated in Table III.

39. The variety occurs not very uncommonly in the descending currents between Cumuliform clouds. Most commonly, however, it belongs to a rather tranquil state of the atmosphere, and is, in all parts of the globe, more or less associated with fine weather, although it is sometimes the precursor of the interfret which characterises disturbance in rather high layers of the air. In the higher latitudes Lenticular cloud most commonly accompanies weather in which the atmosphere near the earth's surface is abnormally warm. Yet, rather rarely, I have seen very perfect Lenticular clouds during a frosty afternoon in winter lying above the summits of low hills, and coinciding in relative dimensions with the relative altitudes of the hills. This fact may afford one clue to the physical causes which determine in some cases the formation of the cloud. Ordinarily the cloud appears in the higher layers of the atmosphere, where there is a downward movement, whether this takes place over the tropical belts of high barometric pressure, or over the summer anticyclones of the higher latitudes ; and we attribute the formation of the cloud in these cases to the meeting of the downward current either with an increasing number of dust particles, or with dust particles of a lower temperature than those existing above. And this is often practically the same process as that which occurs when a slight upward movement of the lower layers of the atmosphere is caused by irregularities in the earth's surface below. When this cloud is formed in the upper layers of the air it very frequently coexists with *Cirrus*, which is itself

an indication of somewhat tranquil weather wherever it lies above areas of high barometric pressures at the earth's surface. It may be mentioned here that the warm weather at the earth's surface commonly associated with this cloud is partly due to "adiabatic" change belonging to downward movements of the atmosphere, and partly to the warming of the earth's surface by the sun's rays.

In its final stages Lenticular cloud commonly disappears by evaporation, or is succeeded by lower types of cloud, and in these instances it has no special value in the forecast of weather. When, however, there is an increasing disturbance in the atmosphere—for instance, when a summer cyclone is advancing poleward over an anticyclonic circulation—Lenticular cloud changes into Turret cloud. This important change, regarded in its relation to changes of atmospheric circulation, belongs to the subject treated of in §§ 44-49 and Chap. IX., and should be attended to with care by the observer.

Stratus Maculosus

40. Many of the sky-scapes due to the occurrence of *Stratus Maculosus* are of very great beauty. The minute rounded masses, compared by some authors to a flock of sheep lying down, produce in perspective an impression of quiet grandeur, and delicate colouring and elegant mottled appearance, which cannot fail to excite admiration in an artistic mind. Plate

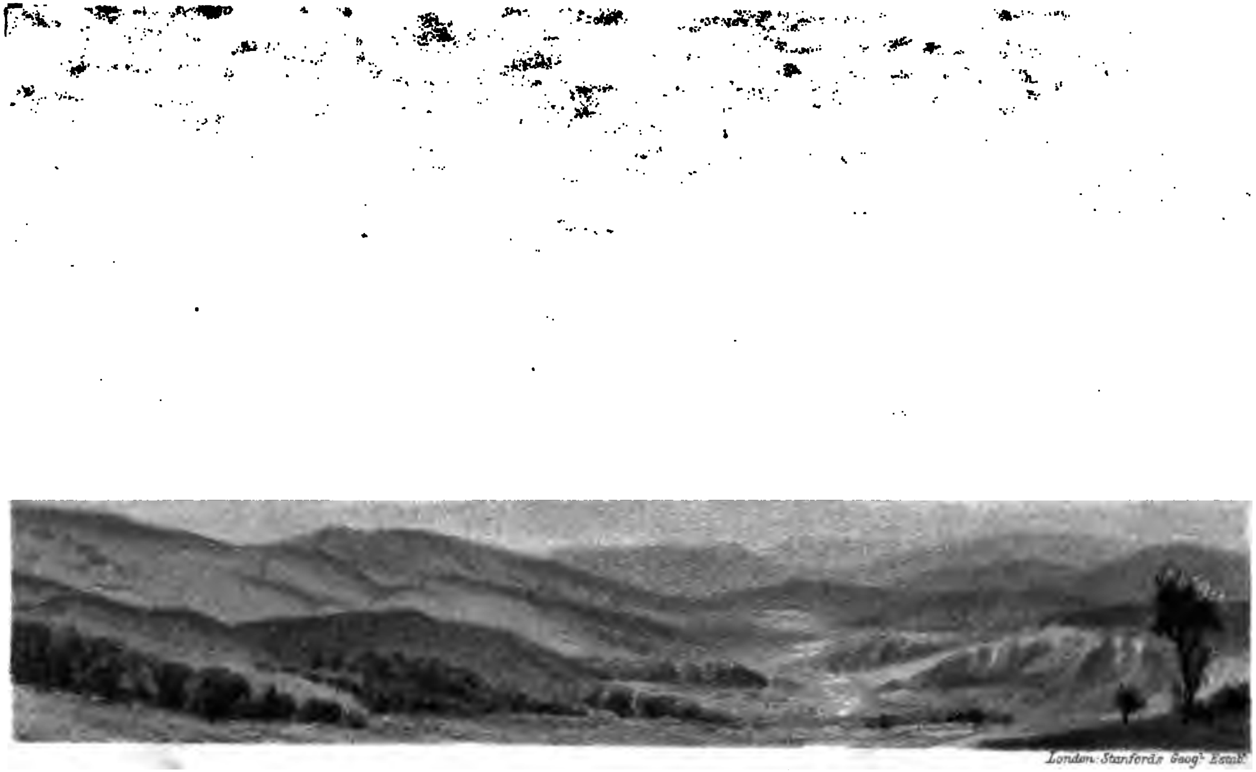
III. is a rough attempt to illustrate a typical specimen of the cloud.

The *Stratus Maculosus*, which is produced between strata of air moving with different but not with extremely different velocities, comprises an exceptionally large number of forms, which are so little definable, and merge so gradually into one another, that none of them can be conveniently described as special minor varieties. Wherever small difference of velocity and direction is concerned the nubecules of Mackerel cloud are sporadic and irregular. But where such differences in velocity and direction of movement are considerable true wave and vortex phenomena are produced, and we have a tendency to the formation of belts or strips of cloud, which, therefore, as in the case of *Stratus Quietus*, appear curved in perspective. This process does not enter largely into the formation of Mackerel cloud, and rarely produces any further effect than to give a lozenge or irregular diamond shape to the nubecules, and to cause the interspaces to appear as rivulets of blue sky, as in illustration (I.).

The exterior edge of a bank of the most loosely formed *Stratus Maculosus* is often, like the exterior edge of *Stratus Quietus*, approximately rectilinear, because the changes of atmospheric conditions and the setting in of new atmospheric currents frequently proceed over the earth's surface in extensive and well-defined boundaries.

41. It is, perhaps, hardly needful to observe that artificial distinctions based on a desire for method are

Plate III.



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STRATUS MACULOSUS

useless where physical processes have no important differences. "*Naturam expellas.*" Very high *Stratus Maculosus* is, to say the least, a near cousin of *Cirro-macula*, which latter distinctly arranges itself in belts. It may be well either to enter a query after the abbreviation of the name in a record of cloud observations, or to state in words that it is doubtful whether the cloud is *Stratus Maculosus* or *Cirro-macula.* As some guide to distinction it should be stated that the former exhibits shaded portions when in such a position that these can be seen, whereas the latter reflects pure light from every portion of the nubecules; and, as a minor difference, that iridescence, or the appearance of prismatic tints, in clouds when somewhat near the position of the sun belongs to *Stratus Maculosus*, and not to *Cirro-macula.* Further, interlacing threads united to the nubecules do not properly belong to *Stratus Maculosus.* Colour assists us in drawing distinction to a certain extent, for the nubecules of *Stratus Maculosus* are of a more orange or reddish tint in the illumined portions opposite to the sun's position than are the fragments of *Cirro-macula.* Nevertheless, the older observers, while unfortunate in the title which they adopted for these clouds, were conscious of a real similarity when they classified *Stratus Maculosus* with *Cirro-macula* under one name, "*Cirro-cumulus.*"

42. It has been shown by several authors that in the process here termed Interfret, § 10, where a current having a given velocity travels over another having a less velocity, whirls or vortices are produced

within which there is a slight uptilt of the lower stratum of air, and here condensation may occur, while on each side of these vortices a slight downward movement takes place, and water is again converted into vapour. This is the simplest physical explanation of the ordinary forms of *Stratus Maculosus*, in which large waves or billows of air are not produced. In short, the cloudlets which give the mottled appearance to this variety are merely the visible summits of innumerable vortices existing between moving layers of air.

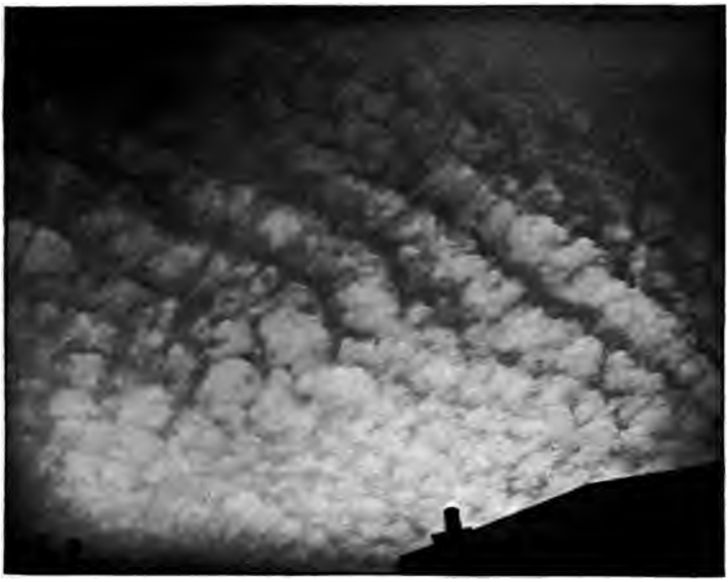


Photo by Arthur W. Clayden, Esq.

ILLUSTRATION I.—STRATUS MACULOSUS.

The altitude of *Stratus Maculosus* varies much, as indicated in Table III.; but the variation is not so great as that of the altitude of *Stratus Lenticularis.*

The mean altitude may be taken as 9000 feet (2754 m.).

43. The cloud belongs, generally speaking, to approximately tranquil weather. It is often composed at night of the *débris* of *Cumulus*, when Inversion movement has terminated and the atmosphere is comparatively at rest. But the occurrence of the cloud has generally been taken to indicate a change of weather from unsettled to settled, or, still more commonly, from settled to unsettled conditions. The interpretation of this cloud as a weather sign is, of course, not quite irrational. When the stormy weather characterising transitory cyclonic systems is temporarily coming to an end, the occurrence of moderate Interfret suggests the fact that, inversion movements having ceased, the rather quiet conditions in which layers of air of varying velocities are superimposed on each other may be anticipated. On the other hand, when the very stable weather conditions belonging in the higher latitudes to areas of high barometric pressure at the earth's surface are beginning to suffer alteration, the *Stratus Quietus* of winter or the *Cumulus* of dry summer weather is superseded by clouds which indicate an increase of horizontal air movement, and this increase frequently precedes the great phenomena of Inversion which in these latitudes belong to bad weather. Over the Polar limits of the belts of tropical calms *Stratus Maculosus* is often very persistent, and cannot be regarded as a prognostic of any change of weather in the locality in which it is observed.

Stratus Castellatus

44. Attention was called to this variety of cloud by the writer in the days when cloud classification was comparatively in its infancy, before the careful observational labours of Hildebrandsson, the physical investigations of Helmholtz, and the researches of other eminent men had enabled us to understand as fully as we now can the formation of clouds of the upper atmosphere. It may seem strange that up to the present date a rather small amount of attention has been given to this very beautiful, interesting, and important variety; but the difficulty has principally lain in the conservatism of cloud classifiers. Turret cloud has been termed by many in late years "Alto-cumulus," and it has also received various other local names more or less descriptive of weather associated with it. To give a single example, clouds of this kind have been called in England "Thunder-heads."

Perhaps nothing in cloudland can equal in beauty the strangely regular and yet wonderfully varied character of this cloud. In its basal portions each nubecule often exhibits a ripple-like structure, which might be compared to that of *Stratus Lenticularis*, hollowed out below, so as to be concave to the earth's surface. The turreted portions above, jagged, and slanting but little forward with the upper current, reflect a brilliant and beautiful light, and in the evening appear almost as if self-luminous. The lower surfaces, seen mostly in shadow, are of a blue neutral tint by day, while the upper portions are of an orange red during the daytime and more white in the late evening; and the colours are especially pure, because the lower atmosphere is, during the occurrence of this cloud, seldom obscured by much haze. The elegance of the cloud is greatly enhanced by its distribution into real belts, which in perspective give it an exquisite beauty. And in this respect the cloud is in marked contrast to the dreary *Stratus Quietus.*

45. *Stratus Castellatus* is a cloud of extreme Interfret, in which not only do adjacent layers of air move with very different horizontal velocities, but in which they are also complicated by more or less difference of direction, so that the phenomena of wave are added to those of the mere vortex most characteristic of *Stratus Maculosus.* So far as an extensive body of this cloud is concerned, *Stratus Castellatus* bears some resemblance to *Stratus Quietus,* being associated with a slight downward movement of the atmosphere. But so far as the growth of the individual nubecules is concerned, this is related to a local upward movement, and the cloud is therefore also structurally akin to clouds of Inversion. It is for this reason that it has been placed next the clouds of that class in Table I.

Thus not only are the summits of turret cloud much elevated above the bases, so that in this respect the cloud resembles those of Inversion, but, further, the arrangement of the cloud is in belts or strips, the effect of which is very striking. It is on those occasions in which there is a great difference both in velocity and direction between the currents carrying *Stratus Castellatus* and the currents immediately underlying it that the cloud is most perfectly and typically developed.

As regards altitude, the variations of this cloud are not very great; and the mean altitude, 20,000 ft. (6096 m.), does not appear to vary much in different parts of the globe.

46. In respect to geographical distribution, this cloud is common near the equatorial calms, very uncommon over the Trade Winds, rare over the tropical calms, and only moderately common in extra-tropical latitudes. It is by no means exclusively a cloud of land-surfaces, although it is rather more abundant over land near a coast-line than over the open sea. It is essentially in the higher latitudes a cloud of summer, and, for reasons which we shall presently give, a cloud of night.

In the higher latitudes, wherever even a minute fragment of this cloud is seen travelling from some tropical point in fine summer weather, it may be taken as an indication of what are called "shallow" cyclonic disturbances moving in a poleward direction; and most commonly its occurrence is a proof that thunderstorms are occurring, or are about to occur, on the tropical side of the observer's station. Much, in these cases, depends upon the strength and persistence of the dry and warm anticyclonic current near the earth's surface.

47. Occasionally, when the area of high barometric pressure at the surface is gaining the victory, and the advancing cyclonic disturbances are dying out, this form of cloud disappears, or is superseded by *Stratus*

Quietus, or by other cloud varieties of less interesting type. But rather more frequently the ulterior development into *Cumulo-nimbus* occurs here and there as the cyclonic disturbances approach. The possibility of hazarding a prognostic of this development, even when the direction of the movement of the cloud is totally unknown, may permissibly be illustrated by the following little anecdote, which at the same time indicates the small amount of attention devoted to the form of cloud. An artist possessed of a keen sympathy with nature, and a most conscientious draughtsman, showed the writer a painting of a sky marked by this cloud in unusually large proportions, occurring over North Britain, and asked what kind of weather was experienced subsequent to the drawing of his sketch. He received the correct answer that a severe thunderstorm occurred within about an hour of the time when the sketch was taken, although in the painting there were no representations of those clouds which are commonly called "thunderclouds." On being asked what certain other painters had remarked about his painting, the artist answered, "They only say, What a funny cloud!"

48. It has already been mentioned that although in the higher latitudes this is a cloud of warm weather, it is also especially a cloud of night. To a great extent this remarkable fact is readily explainable by the circumstance that radiation from the upper surfaces of the cloud rapidly increases when insolation diminishes. But there can be little doubt that there is an indirect connection between

the formation and disappearance of the cloud and the diurnal oscillations of barometric pressure noticed near the floor of the atmosphere. These oscillations, of course, travel from east to west, being dependent upon the sun's position. In the evening, when the afternoon barometric minimum has passed to the westward of any locality, the air which rises above this minimum tends, by virtue of gravity, to flow eastward towards the region in which the nocturnal maximum at the earth's surface is beginning to show itself, and where in the upper portions of the air there is some subsidence of the cloud-bearing layers. Here there is a rapid eastward propagation, and frequently an immense development of *Stratus Castellatus.* On the other hand, before and during the hours of the afternoon minimum, the appearance of this cloud is not often immediately followed by any great further development, and the cloud indeed in many cases disappears.

It is very well deserving of attention that in all latitudes where the cloud appears at all, a diffused sheet of *Cirro-velum,* occurring in the afternoon of a summer's day, and most visible to the west of the observer's position, is frequently succeeded by a most remarkable growth of turret cloud shortly before, at, and after sunset. It is on these occasions that we are about to experience the nocturnal thunderstorms, occurring at great elevations, the magnificence of the pyrotechnic display of which is unequalled. The subject of these thunderstorms must be deferred to the description of *Cumulo-nimbus* (§ 75).

Stratus Præcipitans

49. This cloud of Interfret, rather of vortex than of wave phenomena, classified as a sub-variety in Table II., is a by-product of the first three forms of *Stratus,* and is of little intrinsic importance. Yet, in certain states of the atmosphere, its occurrence throws much light on the physical formation of the clouds of Inclination; and this subject can be most conveniently handled in the present chapter.

Wherever stratiform clouds contain particles of such a size as to precipitate these towards, or to, the earth, these clouds deserve a distinctive title. Not uncommonly *Stratus Maculosus,* sometimes *Stratus Quietus,* and rarely *Stratus Lenticularis,* discharge either water or snow through their lower surfaces, which discharge may reach the earth's surface, or may be reconverted into vapour, according to the temperature of the air near the earth. On hills which are not in the interior of large continents, and on coasts when winds blow from the sea, showers from clouds of Interfret, which clouds have little vertical thickness, and can seldom be mistaken for *Cumulo-nimbus,* are very common, and are especially prevalent in the higher latitudes. In many cases such clouds really emit some particles in an upward as well as in a downward direction, in this respect resembling *Cumulo-nimbus,* although the appearance in perspective of rain or snow blown in front of, or lagging behind, the moving cloud is very easily mistaken for an upward discharge where this latter does not really exist. The manner in which particles may be emitted in an upward direction will appear clearer when we come to deal with clouds of Inclination.

The showers resulting from the formation of *Stratus Præcipitans* are often frequent, thick, and wetting, but the rain-drops are never of large diameter, and the snowflakes are seldom of great size, although the size of snowflakes is not dependent on precisely the same circumstances as those which determine the diameters of rain-drops. In the winter of higher latitudes a rather thick local snow-shower is not very uncommon even when *Stratus Quietus* is alone concerned in the production of the sub-variety here treated of.

50. As may be inferred from the fact that it results from different forms of *Stratus*, *Stratus Præcipitans* has an extensive range of altitude. In dealing with the most valuable information supplied by this cloud we confine ourselves to forms at a considerable distance from the earth's surface. Solitary nubecules of high *Stratus Maculosus* occasionally discharge a little snow, which is evaporated soon after it commences to descend. Out of a dense and compact body of similar cloud, the base of which is, of course, at a relatively low level, precipitation on a much larger scale sometimes occurs. Both phenomena may now and then be noticed at the same time, but in the instance of closely-welded *Stratus Præcipitans,* if the latter be at a considerable height, but little of the precipitation reaches the earth.

Now let us observe the curves taken by the visible lines of the descending particles. These bear a true resemblance to the lines of falling rain, hail, or snow beneath a *Cumulo-nimbus*. But they afford a better illustration of the physical formation of the principal clouds of Inclination. When precipitation of small particles, particularly of ice, either commences at the exact position in which vapour ceases to be vapour and is converted into cloud, or begins to take place out of an already formed cloudlet, or out of an extensive layer of cloud, the visible line of the precipitation is, at the point where it commences, nearly perpendicular, for gravity produces the descent of the particles, and there is very little difference of horizontal movement in the closely-contiguous air-layers. But as the particles proceed downwards, attaining their terminal velocities under increasing atmospheric pressures, they encounter an increasing difference in the horizontal movements of the air, due to increasing friction and to the effects of viscosity. The tail of the precipitation-line is therefore no longer perpendicularly beneath the head, and since the upper currents move, in a majority of cases, more rapidly than the lower, the tail commonly lags behind the head. Differences of direction of movement cause the whole curve to exist no longer in a plane perpendicular to the earth's surface. The twist thus given to the precipitation-lines belongs to the discussion of clouds of Inclination, and forms one of the most interesting as well as the most useful of the subjects dealt with in this monograph. It is important that the student of weather should look carefully at the interesting and somewhat beautiful *Stratus Præcipitans* whenever it occurs at a considerable distance above the earth, not with the immediate object of forecasting weather, but with the aim of understanding the primary cause of the formation of clouds of Inclination.

CHAPTER V

CHARACTERS AND CONTRASTS—CLOUDS OF INVERSION

51. Before proceeding with a detailed description of the clouds under this heading, it may be advisable, even at the price of repetition, to place before the reader the broad distinction in formation between these clouds and those dealt with in the previous chapter. This distinction is, that whereas clouds of Interfret are caused by the interaction of more or less horizontal currents of different velocities or directions, clouds of Inversion are caused by condensation in an upward direction in more or less vertical currents, although the shape of the clouds of the latter class may be affected by differences of velocity and direction in the horizontal movements of the air.

Cumulo-rudimentum

52. Many misleading titles, such as *Fracto-cumulus* and *Cumulo-frustum*, have been applied to this well-known cloud, but these, as we shall see later, lead us to erroneously presuppose that the cloud is a broken-down and degraded form of *Cumulus*.

The range of altitude of the rudimentary cloud is small. The mean altitude, as given in Table III., is 1500 feet (458 m.) above mean sea-level. But in reference to this variety of cloud it is important to observe that in the tropical and extra-tropical latitudes the level is higher in summer than in winter, and that the alteration of level is greater over the land than over the open sea. For the heating of the floor of the atmosphere causes vapour to remain in the state of vapour near that floor, and raises the level at which condensation is possible; and it is the atmosphere which exists over a land-surface which has its temperature specially raised by insolation, since the solid surface conducts less heat downward than the liquid, and parts with more heat in an upward direction.

It will be sufficient to state here first, that this variety occurs in rather different atmospheric conditions from those of actual *Cumulus*, and, secondly, that it is also *Cumulus* in a rough and unwrought state. These two statements are by no means irreconcilable. When fragments of cloud are carried along by wind in the rather low layers of the atmosphere, they commonly adopt the form characteristic of this variety, and the majority of them undergo no further development. A minority, however, under a slight change of condition, are the nuclei or embryos of the true cumulus clouds, which certainly differ considerably in form and appearance from the ova in which they originated.

53. *Cumulo-rudimentum* is one of the most frequent clouds of the globe. It is common in the

equatorial belt of variable winds, and here it tends most readily to become cumulus. It is far the most abundant of all varieties in the Trades. It is by no means uncommon in the tropical belts of high barometric pressure. It is very common in the temperate zones, and it is scarce only in very high latitudes. It occurs over oceanic surfaces as well as over land, but over the sea, if we disregard the influence of latitude, it passes into the ulterior form far less frequently than over land. It is a cloud of slight inversion, occurring where there are horizontal movements of the air, and it is a cloud everywhere more prevalent in the diurnal than in the nocturnal hours. All these characteristics, as well as certain modifications of structure and appearance, more temporary or more local, but highly instructive and useful in the interpretation of weather, which modifications will be described hereafter, admit of the simplest explanation.

When condensation occurs in moderate extent in the lower strata of the atmosphere, a cloud is formed, which, for reasons already partly explained, and to be adverted to hereafter, is developed in an upward direction. In ordinary cases the lowest layers of air travel with least velocity, owing to their encountering the greatest frictional resistance (§ 10), and the velocity of movement increases as we ascend. Therefore, a mass of local cloud ordinarily has a summit leaning forward because the summit moves in advance of the base, and this gives the slanting form of the cloud now under consideration, indicated in its symbol in Table I. Thus, wherever moderate local condensation can occur in a moving atmosphere at no great elevation above the earth's surface, and wherever circumstances unfavourable to the formation of the cloud do not interfere, the variety is readily and abundantly produced. The unfavourable circumstances are the following: extreme augmentation of velocity with altitude, which destroys the form of the cloud by rending off the upper portion, and a superimposed sheet of cloud, which arrests in more ways than one the upward development of condensation. For this latter always checks the insolation necessary to the formation of the local mass of cloud, and occasionally, if at an altitude when the summit of *Cumulo-rudimentum* can combine with the upper layer, it produces another variety (§ 85). It is, further, plain that where insolation is weak, and where the atmosphere is also comparatively torpid, as is the case near the Poles, the conditions favourable to the formation of the cloud are absent.

54. Fragments of *Cumulo-rudimentum* are shown in Plate I. When seen moving with a current, the velocity of which augments as we ascend, without change of direction, this cloud has a different aspect according to the position in which it is viewed by us. Moving "end-on," either retreating from the observer or approaching him, its slanting form is not readily observed, whereas, when viewed at a right angle to its direction of movement, its form is more easily distinguishable. In Fig. 4 the irregular shaded portion represents the cloud, the arrow the direction of the wind, and OO, different positions of the observer.

The amount of slant may be represented by AB, the distance of the head of the cloud from the tail. The amount of slant visible to an observer may be represented by the angle AOB, and it will be seen from the figure that this varies according to the observer's position.

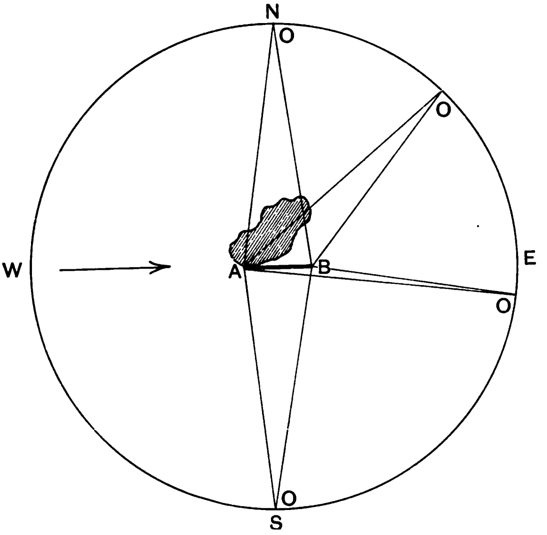


FIG. 4.—SLANT OF CUMULO-RUDIMENTUM.

In nature, for reasons which will be seen in later pages, increase of velocity as we ascend in the atmosphere is seldom unaccompanied with some change of direction in the currents of air experienced; and when the summits of *Cumulo-rudimentum* have a lateral deflection due to change in the direction of moving air, the appearance shown in Fig. 4 is more or less modified. In such cases we have in the higher latitudes of the globe a valuable interpretation and a useful means of forecasting weather. For example, when we are not able to determine from observation the movement of the upper currents, and when theory is either troublesome or likely to lead to uncertain results, the slant of rudimentary cloud very often greatly assists us in determining what is the change of direction as we ascend in the atmosphere, and what is consequently to be the type of coming weather. If, to take a special instance, we notice the heads of these clouds to be moving from a southerly point in Europe, while the general under-current is from the east, we at once know that a more southerly wind prevails at no very great altitude. Thus, in fine weather in April or May in England, when this is the case, we can with some safety hazard the conclusion that a cyclonic disturbance, having a southerly wind on its advancing margin, is progressing eastwards over the western coasts of the British Isles. Such a disturbance, often preceded by fine weather, is itself accompanied by unsettled weather; and after a long spell of fine weather, may be the precursor of many areas of unsettled weather. Thus the modifications of the structure of this cloud may not unfrequently add a little to the weather-wisdom of those interested in the subject.

55. Rudimentary cloud may occur, though not nearly so commonly as Scud, beneath Shower cloud. The condition is unfavourable to its normal type, and we also rarely see this cloud when the shower is near or at its climax, because local upward condensation has then accomplished its work, and precipitation is taking place. Far more commonly it occurs, in large

amount, but in circumstances unfavourable to its form, beneath or constituting the basal portion of what we denominate "*Nimbus*." Whenever doubt exists as to the variety observed, a query or a verbal description may advantageously be inserted in a record of cloud (§ 41).

Cumulus

56. The clouds to which this title is almost universally given are so well known, and have been so frequently described, that it is hardly necessary to say here more than that they are clouds having level, or approximately level, bases, and a massy, rocky, or rounded superstructure. In some cases the cloud may be said to be a cloud of local inversion; yet the process is not completed inversion. Much as *Cumulo-rudimentum* is the occasional nucleus of *Cumulus*, so, as some writers have pointed out, *Cumulus* itself is uncompleted *Cumulo-nimbus.* In *Cumulus* the completion of the process of Inversion is not visible to the eye; in *Cumulo-nimbus* it is visible, and cannot possibly be mistaken.

Wherever it is possible for local condensation to take place rapidly, this condensation itself produces an upward movement of the air, because the cooling effects of ascent are more than counterbalanced by the rise of temperature due to a change of state—to a change from vapour into the liquid form. *Cumulus* has often been compared to the condensed steam issuing from the funnel of a locomotive, to which it bears a more than superficial resemblance. Tyndall has been criticised for the statement that *Cumulus* is the visible summit of an invisible ascending current of air, but nevertheless this statement is in the main correct.

57. A small piece of pearly-gray *Cumulo-rudimentum* has appeared floating in the air, perhaps over one of the inland hills in an atmosphere asleep in morning haze. A small portion of the low stratum of air has attained the condition of condensation. It has received a large increment of heat from the adjacent parts, and in its expansion it has forced upwards those layers of atmosphere which rested upon it. Here in the mixed air and vapour a tem-

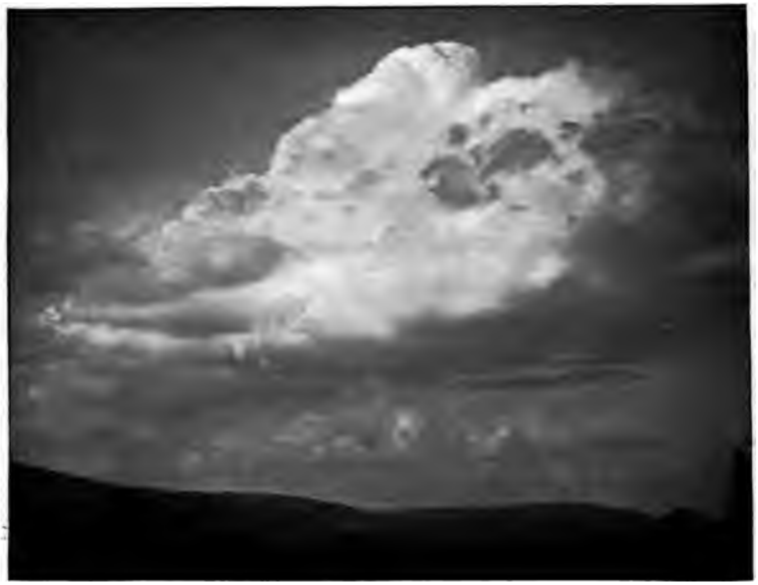


Photo by Arthur W. Clayden, Esq.

ILLUSTRATION II.—CUMULUS FROM WHICH RAIN IS FALLING.

perature is attained at which, further and further from the earth, the particles of visible cloud-matter are formed, the congeries of which was at first nearly structureless. It might possibly be supposed that the volume of mixed air and vapour would be diminished when a portion of the elastic vapour has been converted into droplets of water, but the opposite is practically the case, since the heat liberated in the process of condensation causes an increase in the volume of the remaining mixture, which is greater than the decrease caused by the condensation of the portion. Looking again at the same cloud, we observe that its upper surface is becoming more and more rounded, while its base is flatter than when it was noticed first. Other rudimentary cloudlets have in the meantime begun to appear in other places still over the land-surface, at first very irregularly scattered, but gradually, while we continue to watch them, massing themselves here and there over particular spots of the land with clear atmosphere between them; some of them tending gradually to the hemispherical form characteristic of *Cumulus*. Their tints are also undergoing some change, for the illuminated upper portions, being more smooth than at first, and exposing their convex surfaces to the rays of light, reflect more light to us than previously, and become of a creamy-white hue; while the under portions, in deepening shadow, acquiring a darker neutral, or even inky tint, exhibit an increasing colour-contrast to the heads of cloud.

58. The level base of *Cumulus* differs moderately

in altitude both in reference to the land-surface and to mean sea-level, and the latter variation is shown in Table III. The altitude of the summit has a much larger range of variation, and it has been by some writers exaggerated, probably because they mistake *Cumulo-nimbus* for *Cumulus*, or at least embrace them under a single title. The real extreme altitude of *Cumulus* differs considerably according to its geographical position. In the warmer regions of the globe it is very much in excess of that attained in the colder portions. The altitude of the summit is also greater in the summer of the higher latitudes than in the winter. A low temperature is obviously unfavourable to a great upward extension of a warm column of air, while a high temperature is propitious. For the same reason *Cumulus* is, generally speaking, a cloud of day rather than of night, and it is produced in its fullest development over land-surfaces nearly about the hour of the afternoon barometric minimum.

59. That *Cumulus* should be not only a cloud of the afternoon, but also a cloud rather of land than of sea, is in no way surprising. The surface of the sea is level, and therefore equably exposed, if the upper sky be clear, to the incidence of the solar rays. Its temperature is subject to oscillations which are slow and gradual, and, except where the water is shallow, the difference in its warmth at midday and at midnight is slight. It is also homogeneous, and the amount of evaporation from it is, in an altered condition of atmospheric pressure and of temperature,

uniform. But the surface of the land presents great diversity of inclination to the sun's rays. And even where it is equably exposed, its temperature varies to a great extent. Thus a difference of temperature amounting to 100° F. (55·5° C.) may occur between midnight and noon on stony or sandy soil exposed to the open sky at night and to the full heat of the sun by day, while amidst dense vegetation at no great distance the changes of temperature in the same interval may be very small. Further, the vapour-producing qualities of a land-surface vary to an indefinable extent. Ponds, streams, marshes, arid plateaux, forests, meadows, and corn-fields furnish an indefinitely varying amount of moisture to contiguous portions of the atmosphere, and the varying effects of different processes of vegetation cannot be altogether omitted.

60. An authority, to whose opinion no small deference is due, regards extensive marshes as breeding places of the local clouds of inversion. I cannot altogether adopt this view. It is true that a damp soil favours the formation of *Cumulus*, as of many other clouds. It is also unquestionable that in certain regions of our earth *Cumulus* is formed more freely over marshes than over adjacent districts, and that this fact does not entirely depend upon the phenomena of humidity. But at present investigation seems to indicate that it is rather the unfavourable character of adjacent districts than the favourable influence of the level marsh which determines the formation of the cloud. It is quite impossible to

ignore the fact that irregularities of the earth's surface promote the formation of *Cumulus*, and no one who has studied the subject will doubt that local inversion is assisted by upward movements of the atmosphere on the sides of hills. The fact is certain, and the theory which explains the fact is too simple to need explanation. While the subject of level marshes is being touched upon, a small local observation may be of interest. Dungeness forms the south-eastern apex of what is, at the present time, roughly speaking, an equilateral triangle in the English county of Kent, the base of which triangle in the north-west is about twelve English miles in length. The soil is, generally speaking, swampy and intersected by ponds and ditches. Here the *Cumulus* of the summer afternoon is rare, and its absence marks the promontory in contrast to the occurrence of the cloud-forms over the higher land in the north and north-west.

And this incidentally leads us to the consideration of what seems altogether an exception to the characteristic conditions under which *Cumulus* is most commonly produced, an exception the importance of which cannot easily be exaggerated. In the rear and on the tropical side of cyclones in the higher latitudes *Cumulus* is distinctively a cloud of winter rather than of summer, and a cloud of the sea or of exposed and hilly coast-lines rather than of inland localities. The physical causes to which this fact is due belong essentially to future pages, but must be briefly stated here. In the position above described mechanical law causes abrupt, discontinuous, local inversion movements. These are hindered and interfered with by the more common inversion movements due to local superheating of atmosphere near the earth's surface, which are related to condensation of vapour in summer and over the land. For this negative reason the *Cumulus* of the rear and of the tropical side of the cyclone is a cloud of the winter season and of the sea or of exposed coasts. Excess of vapour, to which clouds in general are due, occurs, *ceteris paribus*, in proximity to oceans more than over continents, and is, of course, a positive reason, of little intrinsic interest, of the formation of cumuliform cloud. It is with hesitation that I do not classify the Clouds of Inversion produced in this particular way, clouds which merit the epithet "stormy," as a sub-variety in Table II. But the distinctions between these and commoner types present some difficulties of demarcation.

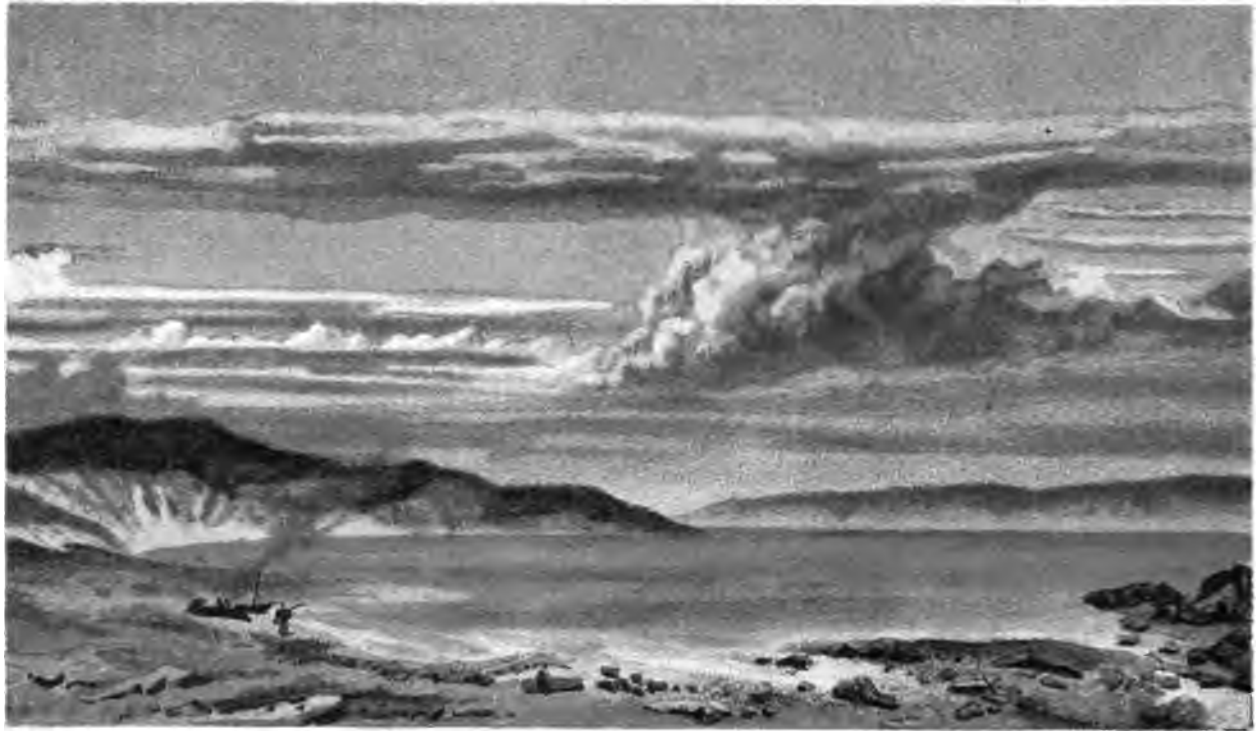
61. Simple *Cumulus* in its usual condition of development is by no means a cloud of unsettled weather, and cannot be regarded as the precursor of any description of storm. For reasons already understood, it rarely occurs in the advent of stormy winds, and the sheet of *Cirro-velum*, which is sometimes in all latitudes the visible premonitor of rain or snow, checks the growth of *Cumulus* by arresting solar radiation and the consequent superheating of the low layers of air. Simple *Cumulus*, it is true, is frequently called "thundercloud" in English, and in other languages has gained corresponding titles. But this

fact is merely due to the inadequacy of the study bestowed on the cloud.

Occasionally, however, *Cumulus*, preserving its hard outline, and nowhere passing above into the shape which belongs to *Cumulo-nimbus*, precipitates an unimportant shower, owing to the union of some of its particles. This is the case in the photograph (II.). In the Northern States and in Western Europe this not unfrequently happens, most commonly in spring months, and as an accompaniment of westerly or north-westerly winds; and the shower thus produced is often one of soft hail or "graupel." A more interesting occurrence has been brought under my notice by my friend, Captain Wilson-Barker, R.N.R., who has seen hard-edged and rounded *Cumulus* in the region of equatorial variables suddenly discharging a smart shower about the time of sunset, and then disappearing. The writer has not himself had an opportunity of noticing this phenomenon, but his testimony could add no weight to that of a most experienced and competent observer. It is possible that hereafter this type of cloud may merit a place among minor varieties, but the subject has received little investigation at the present date.

Cumulo-stratus

62. This is in our nomenclature a true hybrid. Just as it is somewhat humorous to call Cumulus a "cloud of the horizon," because in nature, as in the proverb, "One man's horizon is another man's zenith,"



London: Stanford's Geog^{l} Estab^{t}

CUMULO-STRATUS

so it is rather childish to regard a distant lofty *Cumulus* when a lower patch of Interfret cloud exists nearer to the observer as together constituting a compound deserving the name *Cumulo-stratus.* Illustrations which exhibit such phenomena might, with no innuendo, be compared to a picture of a mule sketched by a draughtsman, who, not having seen the animal, paints a horse standing in the distance, while an ass lies grazing in the foreground.

The mean altitude of the summit of *Cumulo-stratus* above mean sea-level is 7000 feet (2142 m.), as given in Table III. Above elevated plateaux this altitude is increased, and in the middle and higher latitudes, for the same reason as that already stated in reference to *Cumulus* (§ 58), the mean altitude is larger in summer than in winter. The range of altitude is small, its smallness being due to causes which will presently be evident.

63. If, for convenience sake, we term the level at which, in the first stage of a cloud of Inversion, condensation commences, the "plane of condensation," then we may for the same purpose call the level at which the process of Inversion approaches its final stage a "plane of outflow." In simple *Cumulus* there is an outflowing current of air at the top which then moves downwards and round the exterior of the cloud, and this current gives us no visible indications. For condensation has performed its task within the upward-moving pile of cloud, and where horizontal outflow is alone concerned, viz. near and at the upper surface of the cloud, circumstances favour evaporation,

since the vertical movement associated with condensation has ceased. And where compensation is completed in the downflow round the sides of the cloud circumstances are yet more unfavourable to the formation of the visible architecture termed cloud, since the particles are encountering a general augmentation of temperature. Therefore, the interspaces between simple *Cumuli* are commonly regions of clear air, in which a process is going on, which we infer, but the symptoms of which we do not actually see. In this connection the invisible "clouds" whose presence we now detect by actinic effects alone may be referred to. Into the subject I cannot here enter.

Now the "plane of outflow" exists where *Cumulus* is no longer simple, but where another variety is formed, and attention to the phenomena which then occur is of no little practical value to the student of weather. If condensation goes on until congelation is in full action,—and congelation adds, roughly speaking, about one seventh part to the lifting power of condensation,—and if the atmosphere surrounding the summit of the cloud is at such an elevation and at such a low temperature that in the outflow evaporation of the ice particles does not immediately take place, *Cumulo-nimbus* is formed. Where, on the other hand, outflow exists at a lower level, while evaporation in this outflow does not at once occur, *Cumulo-stratus* is produced. It is not difficult to understand the nature of the environment in which the Anvil cloud has its birth. Where, at the moderate elevation of about 4800 feet (1463 m.) above the earth, vapour is ready to be condensed, or has already been condensed, either in high *Stratus Quietus* or rather low *Stratus Maculosus*, in slight or in by no means violent interfret, and where at the same time there is no extreme temperature gradient beyond this elevation, and vapour-tension is also not very great, the outflow from the summit of *Cumulus* readily adapts itself to the prevalent tendency to the formation of cloud at this particular level. In short, *Cumulo-stratus* is formed by *Cumulus* entering a part of the atmosphere where there is slight or moderate interfret.

64. It is a question of minor importance whether in any given instance the upper surface of the *Cumulus* unites itself to a pre-existing visible patch or layer of cloud, or whether in its outward extension it causes a patch or layer to become visible. In a slight majority of cases the process is intermediate between these two. It is, however, a matter of no small interest, both to the local weather-prophet and to one who, by the employment of synoptic cloud-charts, seeks information as to changes likely to occur over an extensive area, to ascertain by observation what is the cloud which may be developed into *Cumulo-nimbus*, and what is the cloud likely to produce only *Cumulo-stratus*. Although it is the object of the present work to assist the observer rather than to glorify the results of observation, it is worthy of remark that not only in Western Europe but in other regions we gain, from some attention to the conversion of *Cumulus* into compound cloud-

structures, considerable knowledge of coming weather. For instance, the upward growth of *Cumulus* on a summer morning may be advantageously watched. When the domes begin to spread out laterally in the kind of shape shown in Plate IV., a critical moment has arrived. In the majority of cases the Anvil cloud is a prognostic of a dry, though often cloudy afternoon in which clouds of the *Stratus* types will prevail, but sometimes, when the lateral outflow in a rather low level is slight and unimportant, the summits of ascending *Cumulus* push through this layer, and begin towards midday to exhibit a rapid upward extension, becoming, for reasons already adverted to, of a purer tint, and reflecting more light to the earth, while at the same time the clouds of Interfret diminish in amount and in thickness. It would be a mistake to imagine that experience in cloud observation enables a man, in the middle and higher latitudes, to part with his barometer and to dispense with all weather study as at present understood. But the probability or improbability of the shower of the summer afternoon can be with due precaution very well estimated by looking at the well-intentioned *Cumulus* in its development into *Cumulo-stratus*, and at the *Cumulus* of evil temper which is likely to become *Cumulo-nimbus;* and the simple question whether it is useful to carry an umbrella in a walk, or whether it is better or not to make hay while the sun shines, may be quickly decided by this kind of observation, and has often been so decided with complete success.

65. While remembering that *Cumulus* (necessary to the formation of *Cumulo-stratus*) is far more abundant over land than over sea, we must not omit to mention that *Cumulus*, where it occurs, is most frequently productive of the compound over water. It is interesting to watch the "degeneration" of the Heap cloud when it passes seaward from the shore. A massive simple *Cumulus* will frequently pass over shallow water, or from one horn of a narrow bay to another, with no great modification of form. But when such a cloud arrives over deeper or open water, and when the circumstances described in § 63 do not exist, the "abacus" which belongs to the Anvil cloud often quickly shows itself. Then the visible column below seems to be falling to pieces like a pillar in the grasp of some hidden Samson. As a matter of fact, the first visible effects of the process of inversion are beginning to cease, and evaporation instead of condensation begins to occur. Gazing on sea and land, we are occasionally impressed by some ideas of changefulness associated with the former and of the stability connected with the latter. The ocean has often been regarded as an emblem of things mutable, and this may perhaps account for a prophecy of a life in which there shall be no more sea, although the old Greek naturally wept with joy when he looked on the sea again after his Mesopotamian excursion. The mountains and hills, from the relative slowness of the changes which take place in them, have been considered types of the permanent. A physical relation of an opposite kind has received less atten-

tion. Mentally injecting the tissue of the atmosphere with a distinguishable colouring, we perceive why the Anvil cloud is often developed out of the Heap cloud where the winds carry the rather low clouds from the shore, and also why all clouds of local Inversion prevail less over the sea than over the land.

Cumulo-stratus Mammatus

66. It has been supposed that the downward festoons or tubercles called in one hitherto ill-distinguished variety "pocks" in the Orkneys and Shetlands, are produced by *Cumulus* tumbling down so as to form knots in a sheet of cloud. Careful attention much modifies the supposition, and further leads us to distinguish in their relation to weather the varieties of cloud which are festooned, while at the same time we become sure that the physical process which produces tubercles convex to the earth is everywhere one and the same. Of least import to the weather-prophet, the festoons of *Cumulo-stratus Mammatus* require to be considered here, and more interesting varieties will be thus readily understood in their proper places.

We have already inferred that slight or considerable interfret may occur where a relatively quiescent stratum of air exists above or below a more rapidly moving layer, although in the organisation of our atmosphere the former must necessarily be an exceptional phenomenon. Where the upper portion of a local Inversion cloud spreads out horizontally, if the conditions are such that the layers of air are here somewhat less rapidly moving than the layers immediately below, and if they have also a temperature and relative humidity (the former chiefly due to condensation in the column of *Cumulus* itself) greater than those of the subjacent layers, Interfret comes into play in the reverse order of vertical distribution to that in which it most commonly occurs. On rare occasions the result produced may be even compared to large Turret cloud upside down, and the appearance is truly stupendous. And we cannot confine the production of the phenomenon to clouds which originate in Inversion. The under surface of one of the clouds of Inclination sinking to a level in which it comes in contact with a colder bed of air, undergoes the reversed Interfret, and, as we shall see, proves a useful weather-sign (§ 113).

67. When the visible upper part of *Cumulo-stratus* is composed of elevated *Stratus Quietus*, or of low *Stratus Maculosus*, the extrusions of cloud convex to the earth's surface give a very rugged, and often a gloomy and threatening, aspect to the sky. A little precipitation may then locally occur, and in this instance the hybrid cloud might be said to be a form of the minor variety *Stratus Præcipitans.* But the observer soon discovers that however ghastly may be the features of the festooned Anvil cloud, it is essentially a cloud of dry weather.

When low *Cumulus* has spread into the layer of *Stratus Quietus* an event sometimes happens in the higher latitudes which deserves a moment's attention.

The column below disappears, because of the diminution of insolation below, yet, owing to the permanence of the cloud of the "anticyclone," the tubercles may remain visible for fifteen hours, or even more, and may be carried over a locality where the real *Cumulus* has not been visible. In such instances the variety might seem to merit a particular title, such as that of "*Stratus Quietus Mammatus*," but the causes which produce this effect are obvious, and [illegible] phenomenon itself is of paltry significance.

Cumulo-nimbus

68. We now come to the true shower-cloud, the cloud of completed visible local Inversion. Awakening attention in its formation, *Cumulo-nimbus* generally exhibits to the spectator appearances that are very beautiful and very grand, and to some spectators, in its accidental postures, phenomena more or less terrible. Massive dimensions impress us, brilliant colour contrasts please us; it is agreeable to any lover of nature to watch for and to calculate beforehand, without much likelihood of an error of more than a few seconds of time, the first disruptive electrical discharge, sweet to hear the rattling or the rolling thunder, interesting sometimes to notice the "time-interval," and even to deduce from it the distance and the altitude of the shower. It is important to the agriculturist and to the navigator to know the probabilities of the violent rain or hail, and of the direction and force of the squall. And the nervous temperament is perhaps agitated by

the fury of a transitory tempest, by the wreck of trees and buildings, by the gloom and anger of the air. Stillness before storm, broken now and then by the cry of the Green Woodpecker, leaflets at rest before a rude carousal, a glassy sea very near the edge of dark and gust-tossed waves, these and many another memory affect the writer while he writes.

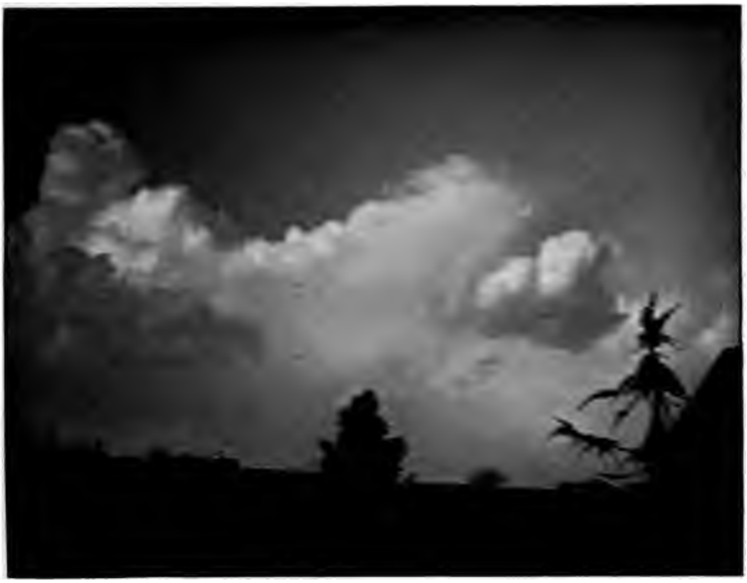


Photo by Arthur W. Clayden, Esq.

ILLUSTRATION III.—CUMULO-NIMBUS.

69. The upward and outward extension of the summits of all shower clouds takes place, when it occurs at all, either simultaneously with, or very shortly before, the precipitation of particles towards the earth. To a certain extent this fact is explained by the circumstance that the extension is the visible indication of the approaching completion of the whole

work of local Inversion. But although trenching here upon the border-land of the unknown, I cannot help entertaining the idea, fully deserving of criticism, that a suggestion made by me some years ago may contain an element of truth. And this idea is confirmed by the fact that the association of upward and outward extension with precipitation towards the earth is much more distinct, and occurs more regularly in order of time in the case of *Cumulo-nimbus* than in *Stratus Præcipitans.* If cloud particles are kept asunder in any degree by electrical repulsion, it is obvious that spherules will possess greater mutual repulsion than spicules of ice. When a water spherule undergoes congelation its electric potential is probably unaltered by change of state, but in the rarefied upper strata of the atmosphere the potential must in congelation be much lessened by change of shape. The edges and points of pieces of ice cause a diminution of potential, and therefore on the hypothesis above mentioned a diminution of mutual repulsion. Thus as soon as, or very soon after, congelation has occurred the particles adhere to one another and form flakes. They then descend, and whether melted or not, in their collision with other particles become of a larger size than before. Certainly the study of the formation of *Cumulo-nimbus* conveys this impression, whether it be correct or the reverse.

70. To that study we here devote our attention. And first it should be noticed that while the mean altitudes of the base and of the summit of *Cumulo-nimbus* are respectively 4000 and 10,000 feet (1219

and 3048 m.), the range of elevation of the base of this cloud is very considerable, and that of the summit also great, as shown in Table III. As regards the base, every one may have seen the "plane of condensation" of the shower cloud crossing a rather low hill, while, on the other hand, to mention a single example, I have seen the base of a *Cumulo-nimbus*, formed out of *Stratus Castellatus*, completely clearing the top of Mont Blanc. In reference to the summit, this sometimes in the higher latitudes lies completely beneath the apex of a mountain of very moderate height, while, on the other hand, careful measurements prove that in the lower latitudes, and even in the summer of middle and higher latitudes, this is

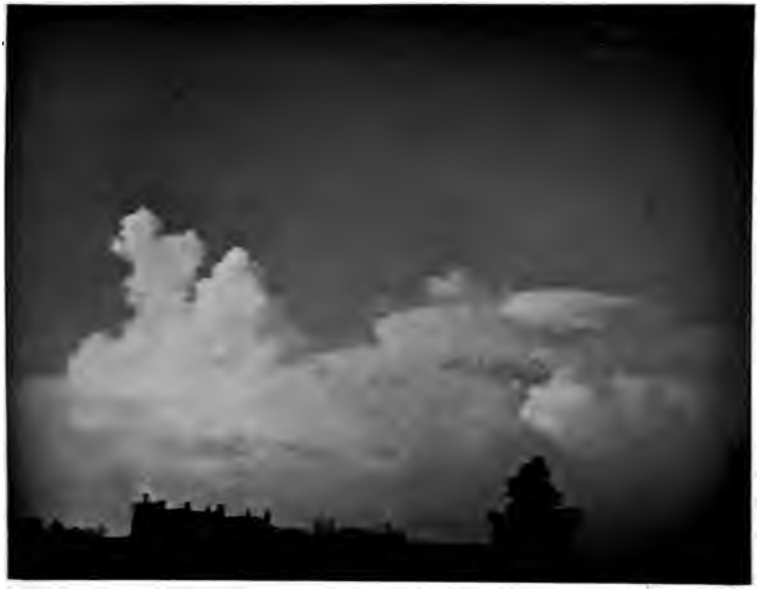


Photo by Arthur W. Clayden, Esq.

ILLUSTRATION IV.—CUMULO-NIMBUS (SAME CLOUD 10 MINUTES LATER).

occasionally only exceeded in level by *Nubes Fulgens*, though it is greatly exceeded by the latter.

71. In a region and on a morning when the formation of local showers seems antecedently probable, the observer looks at the agglomerations of ascending Cumulus. He thoroughly understands that when these clouds spread into the typical compound *Cumulo-stratus*, the domes not penetrating above the level of Interfret, the formation of the great local shower is extremely improbable, and that the chance of its occurrence may usefully be dismissed from consideration. He watches the summits rather than the under surfaces of cumuli which are not near the zenith. By and by the hard outline becomes a little soft. A glance at the base of the cloud, if this base be conveniently visible, soon gives some notice that precipitation from the cloud has begun, lines of descending matter being discernible. On a warm day, whether or not the precipitation reaches the earth, if the *Cumulo-nimbus* has a lofty and now congealed summit, the first flash of lightning will probably take place, but the moment of its occurrence must be left to the experience of the cloud-gazer, being dependent upon temperatures, humidities, latitudes, geographical positions, and other factors. Neither is it necessary here to enter into the question whether the flash will touch the earth, for that topic has been dealt with, perhaps unsatisfactorily, in other books and papers. It is enough to say that the precipitation is a very imperfect conductor, through which

disruptive discharge takes place. And when the discharge has occurred, diminution of mutual repulsion seems to favour the union of particles, and a sudden increase of precipitation, itself favouring the imperfect conduction, is likely to occur, so that a fierce dash of rain or hail often follows a lightning flash. All this is "plain sailing," and questions about "conservation of energy" are beside the mark. But it may be convenient here to advert to a not very uncommon phenomenon, which I have described elsewhere. The flash through the blue sky which the ancients regarded as an augury of terrible events is not a little interesting. It may be seen at a distance in the daytime when the shower is not near the sun's position. It is rather surprising when very close to the non-observant. I will quote a single instance. At Breinton, near Hereford, in the year 1873, "A very remarkable flash of lightning occurred on July 16th. The morning was showery, and thunder-clouds formed in different directions at 9 A.M. About 10 a large cumulus rose in W.S.W., and broke in rain about five miles from this place, its summit at the same time, as is usual in incipient storms, assuming a cirriform appearance. The first thunder-clap soon followed, and was succeeded by seven or eight others as the storm travelled to N.W. The sky overhead was quite clear, and also over Hereford, three miles east of this place, and the storm-cloud had a very isolated appearance, though there were other distant clouds on the horizon. I was standing in my garden watching the distant lightning, when a flash left the cloud two or three miles to W.N.W. of this place, passed almost directly overhead, but a little to N.E., and descended upon Hereford, traversing in a horizontal direction a space of about five miles of clear blue sky, devoid of cloud. The clap commenced nearly in the zenith, the time-interval showing the part of the flash nearest to this place to be about one and a half miles; it then became loud both over Hereford, in the east, and in the storm, in the west. Hereford lies comparatively low, and the electric fluid travelled near the earth over high ground covered with trees, buildings, etc.; avoided All Saints and St. Peter's spires, very near which it must have passed, and singled out a house in the more eastern part of the city. The house struck is lower than others in the same row, and the adjoining house on the west has much higher chimneys. Not much injury was done, though two persons suffered from a temporary paralysis. The inhabitants of Hereford, few of whom had noticed the distant storm, were greatly startled by the terrific flash and clap under a clear sky and brilliant sun.

"As observed here, the flash appeared straight, almost resembling a rocket fired horizontally, but Mr. Isbell informs me that as seen in Hereford it was very zigzag, and seemed to come along near the ground" (Symons's *Monthly Meteorological Magazine*, vol. viii. pp. 106-107).

This occurrence is most commonly noticed when there is a little *Nubes Informis* outside the shower, and is especially likely to happen just at the time when the shower has passed off and a man is setting out for a walk, and I have at times noticed it in terrific proximity. There is nothing in its physical concomitants which is extraordinary. The humid air left behind by a progressive shower, especially when low fragmentary condensation occurs, is a decent imperfect conductor, and a study of an electrometer shows us that in both places the changes are very sudden and of great amplitude.

72. The subject of practical value is again the change in the summit of the cloud. Let this change be carefully watched: and it cannot be thus watched where the smoke from a large town or from extensive manufacturing districts interferes. Where, as in the winter season of high latitudes, it takes place quickly, and at no great elevation, a moderate or slight shower, mostly of snow, is all that is likely to occur. Much the same statement may be made with reference to *Cumulo-nimbus* formed in summer over the hills of high latitudes, because here the Inversion is quickly brought to its climax by the upward movements mechanically produced in the atmosphere carried over the hills. The showers may be sharp and strong, but the whole process is not of very great vertical dimensions. Now two facts call for special notice. First, it is seldom that any great variation occurs in the character and altitude of shower clouds developed in different hours of the same day, and this is even partially true when several consecutive showery days are considered, because, however local the inversions may be, the level at which they are completed cannot

vary suddenly very greatly, except in so far as a complete change of weather conditions, obvious to the observer, may take place. Secondly, in England, and in some other parts of the globe, a climax of Inversion often occurs about noon, and is followed, at or a little later than the hour of the afternoon barometric minimum, by a greater climax. The "afternoon thunderstorm" of many inland places in rather low latitudes is too well known to require to be specially described. The noon-day shower of many regions is neglected because it is slighter, and is also less regular in respect of time. It seems as though insolation in the morning produces the inversion which is temporarily satisfied, and the great "heat-lag" in the afternoon produces the second and more important inversion. But this explanation is obviously inadequate, and the subject is, so far as my knowledge extends, at present rather obscure. In practice a study of the height and character of the upper portion of *Cumulo-nimbus* at noon gives us a good idea of what is likely to be the greater development of the cloud in the afternoon. But the observer must remember that a good deal in these cases depends upon changes in general weather conditions. For example, in the extra-tropical latitudes a *Cumulo-nimbus* at noon occurring on the polar side of a poleward-moving shallow summer cyclone may be taken as a prognostic of a much more well-developed *Cumulo-nimbus* in the afternoon. On the other hand, when a cyclonic disturbance is passing away from any place, and weather conditions are becoming more settled, the *Cumulo-nimbus* of noon may be either followed by one of no greater dimensions in the afternoon, or by the total disappearance of Inversion cloud.

73. On a land-surface in summer, after a period of dry and warm weather, a rainy day is frequently followed by a day, or succession of days, characterised by the formation of *Cumulo-nimbus.* And this may be the origin of the idea that thunderstorms succeed rain, and are the precursors of another spell of fine weather. On the other hand, *Cumulo-nimbus* belonging to unsettled weather may be the termination of a period of drought. Such periods are in the British Isles generally rather short, and the proverb about "three fine days and a thunderstorm" is not altogether erroneous in reference to the feeble morality of an English summer.

74. The brushed-out appearance of the upper portion of *Cumulo-nimbus* must be familiar to any cloud observer. It is important to notice that only in those states of the atmosphere in which there is no great increase of velocity with altitude, the horizontal sheet, at the time when the cloud is reaching its final development, extends equally in all directions. Ordinarily, velocity increasing with altitude, one portion of this sheet extends much further than the other, and when we have no other indication of the direction of movement of the higher layers of the atmosphere, the forward extension of the summit of a distant *Cumulo-nimbus* very frequently gives us a sign of what this direction is. In Plate I. there is a slightly marked extension from

the left towards the right of the painting, which nearly coincides with the direction of the wind in the lower clouds. In Illustration V., in which a local shower cloud is shown in the early evening, the extension is more clearly delineated. Sometimes this extension shows that the upper current has a

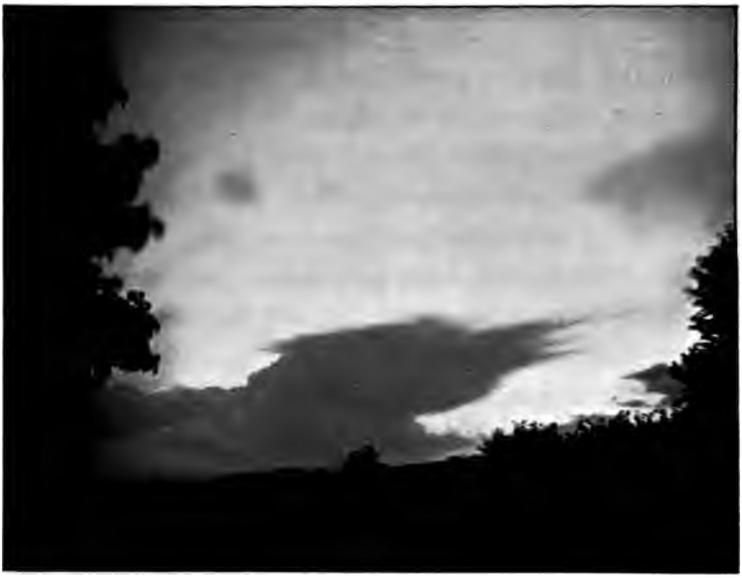


Photo by Arthur W. Clayden, Esq.

ILLUSTRATION V.—CUMULO-NIMBUS (EVENING).

direction inclined at some angle to the lower, or exactly opposite it. And this kind of indication is frequently of no small value to the student of the subject. Occasionally, the forms produced by extension, even before congelation has completely performed its work, may be compared to swans' necks surmounting the lofty cumulus, and because Interfret then plays an important *rôle* in its connection with

Inversion, such an appearance may be the precursor of a very violent local shower.

75. This leads us to a short consideration of the tremendous *Cumulo-nimbus* which (§ 48) is the occasional development, here and there, of the most interesting and active *Stratus Castellatus.* When the latter cloud disappears in the morning (§ 48) the ordinary *Cumulus* of warm weather frequently succeeds at a later hour, and developing into *Cumulo-nimbus,* may produce showers of moderate dimensions. But where in the later hours of the day, Interfret changing into Inversion, the Turret cloud is fully developed, it forms the greatest, and in some respects most formidable thunderstorms in most regions of the globe. Then the domes of the great shower cloud are the highest; then the large hail devastates the vineyards, or destroys the standing corn; then the timid temperament is panic-stricken; then the sudden floods rush more wildly than at other times out of the land which has been most skilfully drained, and the river rises with appalling rapidity.

It must not be supposed that the thunderstorms of the evening, still less that the nocturnal thunderstorm, causes accidents from lightning nearly so often as the shower of the lowland, especially characteristic of the rear and of the tropical side of the cyclones of the higher latitudes, at least in proportion to the number of electric discharges which take place respectively in the one and in the other. The thunderstorm of the night often produces a magnificent display, which, over a great city, in its continuance through several hours, causes very few accidents indeed, while in the short-lived *gewitter* of low level and of the winter season a very few flashes may splinter the mast of the boat on the sea, or wreck the farmhouse on the moorland near the shore.

Cumulo-nimbus grandineus

76. The advantage of classifying the local hail shower as a minor variety is almost wholly practical. The subject of the probable formation of hail has been much handled, in a general way, by such authors as Ferrel, and more specially by others, among whom not the least eminent is the Hon. Rollo Russell. The student can glean a good deal of information from the works of authors like these. Here we must necessarily confine our attention to a modicum of theory and to an ounce of well-known fact. From the time when Volta suggested the hypothesis of oscillation of pellets between differently electrified clouds up to the present date, the formation of hail seems to have taxed the ingenuity of investigators, and we may conclude that there is more difficulty than one might anticipate in the subject.

77. In the hailstorm "the ascending currents are so strong, and reach so high up into the upper strata of the atmosphere, that the raindrops are carried up into the cold regions above, and into the central part within the isobaric and isothermic surface of the freezing-point, where they are frozen into hail"

(*Popular Treatise on the Winds*, ed. i. p. 420). Within the hail stadium water spherules are condensed into ice. Snow usually forms the nucleus round which the layers of harder ice arrange themselves. Whenever Inversion is moderate, moist pieces of snow may unite to form not the true flake, but the nodule, which, where it reaches the earth or is encountered by the aeronaut, is commonly termed " soft hail," "grupple," "graupel," or "grésil." But where Inversion is very great, as described in § 75, the hailstorm encounters layers of air of differing temperatures and humidities. Rapid motion promotes rapid evaporation in the ice-surface, and intense cold favours the formation of additional hard ice. It is scarcely needful to describe here either the remarkable shapes or the sizes of hailstones. The hailstone of Seringapatam may or may not have been as large as the average elephant employed in that neighbourhood. I do not happen to have seen a hailstone quite so imposing. But it is certain that hail not uncommonly destroys poultry and partridges, almost certain that its impact sometimes sends a human being to another sphere. Even in England, with a temperature above the normal, in the month of August hail may occasionally be seen lying about in ditches for four days or more.

78. Study of the upper surface of a distant *Cumulo-nimbus* in the daytime, if the air is clear, enables a practised observer to know whether he is looking at a hail shower or not; and if the shower be *Cumulo-nimbus grandineus*, and progresses in the right

direction, to wire to an acquaintance and warn him of the approach of the hail, should he be so disposed. The domes, while distinctly congealed, do not in the earlier stage of the shower spread out much laterally, and if the shower be one of the grander kind, are at a considerable level above that of *Cirro-filum*, which may sometimes be seen on a warm afternoon between the upper part of the distant shower cloud and the observer.

And this leads us to a subject which has received a good deal of attention. Meteorological observers have commonly remarked that a fall of hail is of infrequent occurrence "except during thunderstorms." Generally speaking, the hail of the thunderstorm occurs in the earlier stage of the development of *Cumulo-nimbus grandineus*, soon after precipitation has commenced, although the first large drops are, near the earth's surface, commonly rain, for the simple reason that the lower strata of the air are at first warm enough to melt the falling hail. But by some observers, at certain localities and at certain seasons, hail is regarded as characteristic of the termination of a shower, for this reason, that the warmth of the lower beds of air may continue to melt the falling hail until the shower is nearly at its end.

Hail showers have been often, quite correctly, regarded as phenomena of the day rather than of the night. By this time the reader is familiar enough with the fact that the commonest violent local inversion takes place in the daytime, and especially in the afternoon. Nevertheless, destructive hail occurs in the night in the thunderstorms developed out of *Stratus Castellatus*, and many cases may occur to the memory. A single example will suffice, which was interesting to a dweller in London or Cambridge. The hail shower which crossed the English Channel, moving towards the north-east above a northerly or north-easterly breeze, wrought some havoc on the night of August 2nd to 3rd, 1879.

Cumulo-nimbus Nivosus

79. Very little need be said about the snow shower of Inversion. It is useful to distinguish it, as a minor variety, because it differs in physical characteristics and in its association with phenomena of weather from the other shower clouds of Inversion; and it is convenient to give it a symbol of its own, because the use of this saves some time and trouble to any one who keeps a record of cloud observations, or who assists in charting such observations on a cloud-map.

In altitude the variety is inferior to that which has immediately preceded it in this book. Belonging properly to the winter of the higher latitudes, though common also over mountains near the equator, *Cumulo-nimbus Nivosus* is readily formed at no very great height above the earth's surface, and the mechanical process is completed without an ascent to the very high level of the largest hail shower. When the snow stadium is reached by a cloud of Inversion, congelation takes place not above but below the level at which the kernels of hard hail are produced. For whether the cloud is formed in the winter of high latitudes or over mountains near the equator, snow which falls locally to, or nearly to, the earth in the form of actual flakes does not require the great, active, and lofty Inversion commonly requisite in the cases in which we experience heavy local hail. The short description of the way in which hailstones seem to be produced (§ 77) is itself an explanation of this fact, for the hailstone has to pass, whether it be really at all carried up and down in alternating currents or not, through layers of air of great vertical thickness and of very low temperatures. The snowflake quietly descends, and does not need to traverse a great distance, and a very low temperature is actually adverse to its formation. Spicules of ice do not adhere to one another if they are very dry, and when they do not coalesce, their descent is extremely slow, and we hardly experience what can be called a snow shower at all.

80. Moreover, it seems impossible that the snow which reaches the earth from *Cumulo-nimbus Nivosus* is formed at a very great altitude. For even the large hailstones which have great terminal velocities take a considerable time in reaching the earth. But a snowflake which has comparatively an exceedingly small velocity must take a very long time. In fact, if the cloud were moving, say, at the rate of about twelve miles per hour, we should get no snow till the cloud had long passed over and was very many miles

away. But since in a snow shower moving at this rate the snow never lags more than five miles behind the cloud, and very rarely, if ever, as much, it is obvious that the height of the upper part of the *Cumulo-nimbus Nivosus* cannot conceivably be very great.

Very large flakes are in all circumstances an indication of a comparatively high temperature, and this fact is too well known to need further attention here. The local snow shower is also not uncommonly accompanied by lightning and thunder, for obvious reasons already implied.

In the higher latitudes, although Inversion, in inland localities, is greater by day than by night, yet, on the other hand, a moderate fall of temperature of course characterises the night, other circumstances being disregarded, rather than the day. The two factors of the snow shower may be said to counterbalance each other. On the ocean and the exposed coast the snow shower of the higher latitudes, of the rear and tropical side of the progressive cyclone, is fiercer by night than in the day (§ 75).

In the rear of passing *Cumulo-nimbus Nivosus* it is a common thing to see an assemblage of snow lines, which are evaporated before they reach the earth, hanging in the air. At one time the writer suggested that this might merit a title of its own, such as "Snow-rack," because its formation throws some light on the development of clouds of Inclination. But it seems more advisable to consider that development elsewhere.

Cumulo-nimbus Mammatus

81. We here come to a kind of cloud which has been already mentioned, in regard to its similarity of formation and the contrast of its weather conditions, to an inferior sub-variety, with which it seems to have been often confounded (§§ 66, 67). Although the festooned shower cloud is not common, its peculiar, and to some observers, rather ghastly appearance has attracted some attention. The cloud may be described as the horizontal, or nearly horizontal, "hat-brim" of a local shower, having a number of more or less hemispherical protuberances hanging from the base of the extended part. These festoons, which are completely congealed, never appear to me to bear any very close resemblance to those of *Cumulo-stratus Mammatus,* for they are larger, although, being at a much greater altitude, they do not always look larger; they are also much more regular in shape, and they have far smoother curvatures.

82. Where *Cumulo-nimbus* has mounted into a region of the atmosphere in which visible lateral extension occurs above layers which, from any cause, are colder than the air within the outflowing portion of the cloud, we have conditions favourable to Reversed Interfret associated with Inversion. This most commonly happens where the local shower cloud is approaching the final period of its existence, because the visible lateral outflow commonly takes place at this stage. It is the fact that Interfret takes place in a downward direction between this

lateral outflow and the colder stratum beneath that makes the cloud rather a rarity, and has caused us to name such a process "Reversed Interfret" (§ 11).

Cumulo-nimbus Nivosus occasionally adopts this kind of architecture; but only occasionally, because that sub-variety exists at no very great altitude, because it occurs in wintry conditions which are unfavourable to Reversed Interfret, and, above all, because in the snow shower the grand process of Inversion is not sufficiently actively developed. It is in the old age of the thunderstorm and of the great local hail shower that the wrinkled features, the crows'-feet near the margin of the eyes of the dying storm, are most vivid and most impressive. Here we notice a phenomenon which is simple of explanation, but which merits observation. It is where some change of wind brings colder air beneath the lateral outflow that the process of the formation of tubercles convex to the earth most readily takes place. To take an example: When a local shower, travelling in Western Europe from a west or south-west point, has passed away from an observer, and the lower wind is veering and bringing with it a fall of temperature, while the shower itself is actually dying out, then, looking towards the north-east or east, we may notice the festoons, and they will be on the left-hand side of the shower cloud.

Precipitation takes place very little, if at all, out of the actual tubercles, but it may still be occurring in moderate amount in another part of the cloud-structure, and in the example last given this will be on the right-hand side, or in the south portion of the cloud, for the cooler air is entering below upon the other side.

83. In cases which are, generally speaking, of yet rarer occurrence something happens which may at first be regarded as in contradiction to that which has been already said. The festoons are then the advanced guard of the progressive afternoon thunder shower, and in their rear Inversion may not have attained its climax, and heavy local precipitation may be taking place. Here the forward extension of the canopy covers an atmosphere which, however sultry its lower part may seem at the earth's surface, is nevertheless cooler than that immediately within the canopy itself, and than that in front of the whole disturbance. This fact is partly due to the thermal effects of condensation and congelation, wherever falling rain or hail is not locally cooling the bed of air immediately beneath the shower; and partly, too, it is owing to the diminution of insolation, for the air beneath the canopy is shadowed by the existence of the latter, so that here it might be said that the exception proves the rule, or at least that the occurrence is not particularly strange. I have seen the festoons hanging in front of an advancing thunder shower to a lateral distance of fourteen miles beyond the locality of heavy precipitation, and in the warmer parts of the globe this event is not altogether negligible. The *Cumulo-nimbi* are considered to be related to that part of Solar Physics which deals with

periodic sun-spot phenomena. But this subject is not ripe for discussion here.

84. It has not been thought advisable in this work to deal with the phenomena of spouts and tornadoes as forms of cloud, although they undoubtedly accompany and are connected with clouds of "completed Inversion," and are spoken of by many people under the title "Funnel clouds." Such phenomena belong properly to the subject of cyclones (chap. ix.).

Nimbus

85. We now come to a cloud of Inversion which is not strictly local, but is spread over a large area. *Nimbus* is a truly composite cloud, being made up of united or partially united clouds belonging to different varieties or sub-varieties. It consists of a huge dark bank of cloud without any apparent structure, covering perhaps from 100 to 50,000 square miles, and usually bringing with it "dirty" and windy weather. In its lowest portion we generally see some amount of *Nubes Informis* or Scud, but more frequently a rugged, patchy floor of *Cumulo-rudimentum*, with the heads of the forward-slanting pieces of cloud buried in layers above. These superimposed layers consist of poorly-developed clouds of the Interfret type, chiefly *Stratus Maculosus*, which we do not see in its elegance simply because our view of it is more or less obstructed by the clouds below. Above these layers again we may have *Cirro-macula*, or there may even exist a large quantity of well-developed clouds of Inclination.

Now it will be seen later when we come to clouds of Inclination (§ 90) that the union of these clouds with lower clouds generally produces rain. Thus, if we have a bank of *Nimbus* united to clouds of Inclination above, we shall have extensive precipitation. But if we have no Inclination clouds, or perhaps only a little *Cirro-macula* above, we shall be shadowed by a heavy, dull, and rainless canopy, which we might call "Rainless *Nimbus*."

It seems probable that this cloud owes its origin to extensive condensation over oceanic surfaces causing inversion currents of great extent. These currents are complicated at a higher altitude with strong horizontal currents causing Interfret action. The great bank thus formed is the "nucleus" of one of those moving areas of low pressure called cyclones, and always exists in the interior front and tropical side of these disturbances in higher latitudes. In lower latitudes it is often accompanied by very violent rain.

It will not, therefore, appear strange that *Nimbus* has been classed among clouds of Inversion. For although a great deal of the cloud-matter of which the whole mixture is composed consists of Mackerel cloud, yet it is the original and important Inversion movement on a large scale that is the principal factor in its formation and bearing on weather.

86. It will not be necessary here to say much about the two varieties of *Nimbus* given in Table II., § 23. These two varieties, *Nimbus Grandineus* and *Nimbus Nivosus*, are exactly similar to the corresponding varieties of the local *Cumulo-nimbus*, and enough

has been said under these clouds about the formation of hail and snow to explain the reasons for distinguishing these under separate titles. It will be necessary, however, to remember the difference between these minor varieties of the Shower and the Rainfall clouds. The Hail Shower differs considerably from the Hail-fall, and the local Snow Shower which forms a light sheet of snow over the ground is very different from the persistent Snow-fall, which forms huge drifts, blocking the railways and the streets, cutting the telegraph wires, and causing death from exposure and starvation.

CHAPTER VI

CLOUDS OF INCLINATION

87. WE now come to deal with the last great genus of clouds in our classification. Though fewer in the number of their varieties, less striking to the ordinary observer's eye, and perhaps less common as a whole, yet clouds of Inclination are perhaps more important and more indispensable to the correct forecast of weather than any others. For this reason it seems desirable, before describing each separately, to give a short general description of the structure and characters of the whole class.

Clouds of Inclination resemble rather the clouds of Interfret than the clouds of Inversion in general appearance. It is scarcely likely that any but the most unpractised observer would confound *Cirrus* and *Cumulus*, yet it is an unquestionably difficult task to describe the distinction between *Cirro-macula* and *Stratus Maculosus.* In fact, so close is the analogy between some of the Interfret clouds and some of the clouds of Inclination, that we cannot help seeing that the phenomena of Interfret play an important part in that part of cloudland which is the domain of *Cirrus.* But, on the other hand, the general process which gives rise to the name "Inclination" is of a nature entirely distinct from and much simpler than that of Interfret or of Inversion.

88. This process, already briefly treated of in chap. i., may be described as follows :—

When, from any causes, a layer of air containing water-vapour has been carried to a very high altitude into layers of air which are very rarefied and of very low temperature, condensation will commence as soon as this layer has been sufficiently cooled, and this will be helped by Interfret action between it and the surrounding layers. The minute water particles thus formed immediately fall by their own weight through the cold layers, and are almost as immediately frozen into ice dust. If their fall still continues, they are carried through currents which grow gradually warmer but move gradually slower and slower, owing to friction, until finally they experience a temperature which forbids their existence as ice particles, and converts them first into water particles, and then, probably very soon, into their old form of water-vapour. The cloud thus formed will obviously present a curved form to the eye of an observer, for each portion will lag behind the more rapidly moving portion above it. This curve has already been noticed in connection with *Stratus Præcipitans*, and it is the careful observation of this "slant" or "twist" that gives us so much information as to the force and direction of the upper currents.

89. The process above described is that of the simplest type of Inclination clouds, and it is evident

that this process may be much complicated. The particles may, as it were, be checked almost at once in their fall, or may, after falling a considerable distance, be met by cross currents of warmer or colder air, and thus Interfret action at different levels may take place; moreover, the whole process may occur in connection with great Inversion movements. In fact, as will be seen later, the very existence of a quantity of moisture at such a high altitude is generally due to one of these latter movements.

The above description also applies to the normal formation of clouds of Inclination, but it will be evident that the same result would be obtained if the particles, instead of falling downwards, were emitted in an upward direction. Whether it be a great Inversion movement, or whether it be a geographical obstruction such as a mountain, that is the cause of an ascensional moist current, the curved form of the cloud produced will be reversed, but otherwise exactly similar to that produced by falling particles. In the former case the cloud produced is a true Inclination cloud, in the latter it is *Stratus Præcipitans* (§ 49).

90. But the physical constitution of clouds of Inclination, in that they consist almost entirely of minute spicules of ice, is a feature which distinguishes them especially from other forms of cloud. And it is in their electrical relations that we observe a special contrast. For water spherules, owing to their spherical shape, are adapted to hold the maximum

charge of electricity, whereas the points of the ice needles discharge the electricity in streams, and the needles arrange themselves end-on in lines or threads which are approximately parallel to one another. Thus clouds of Inclination are far more perfect conductors of electricity than those clouds which are composed of particles of water, and their character in this respect plays a most important part in the production of rainfall. With few and rather unimportant exceptions the rain-producing clouds are composites formed either by the close approach, or still more commonly, by the actual union of clouds of Inclination with other cloud-forms. It is when one of the huge clouds of Inversion, heavily laden with a great charge of electricity, has towered up and invaded the territory of the clouds of Inclination that the roar of battle begins. If we watch him carefully, we see that the top of his mighty head has suddenly lost its rounded appearance and assumed a hairy look, as if some invisible hand had plucked him by the beard and he is bristling with anger. But what has really happened is this—he has met with or made for himself a good conductor, in fact, has become "cirrified." This conductor, consisting of ice needles, gradually draws off the charge of electricity, and this lessens the mutual repulsion of the water particles, which therefore unite, forming drops, and fall to the earth as rain. It is for an exactly similar reason, as has been mentioned in § 71, that a large disruptive discharge to earth is generally followed by a heavy dash of rain. It is obvious also that if for any reason the water particles become frozen at any lower part of the cloud, that part at once conducts away electricity, and thus we have a fall of rain or snow without any actual invasion of the *Cirrus* level. Of course such a phenomenon is not common, but the fact that it does sometimes happen tends greatly to support this theory.

We thus see that it is in their electrical relations with other clouds that clouds of Inclination have such an important effect on weather.

Nubes Fulgens

91. It would not be strictly true to say that Luminous cloud is a cloud of Inclination, but it is convenient to notice it under this class, as it is certainly a cloud of the "upper currents." This cloud has received much attention of late years, owing to its mysterious and remarkable character. It exists at an altitude far greater than that of any other cloud associated with our own planet. It appears to the casual observer as self-luminous, and suggests the idea of luminous light. But, from various reasons, the conclusion has been drawn that Luminous cloud merely reflects the rays of solar light; and we might compare its appearance to the mirrored volcano gleams often mistaken for flame in the dust cloud hanging at night over the crater of a burning mountain. It has not been shown to be distinctly associated with auroral or sun-spot phenomena. Though perhaps not composed of

congealed water, it may fairly be classed as a cloud of Inclination, its form being determined by the descent of congealed matter through air-layers of varying velocities and directions. Observation of its movement and filature (or direction of slant) would greatly add to our knowledge of currents of air at a great elevation. But perhaps the most remarkable fact in connection with this extraordinary cloud is that it is gradually decreasing year by year, and will, in all probability, soon become extinct.

Cirrus

92. *Cirrus* may be described as a vague, thin, very lofty cloud, resembling in appearance tufts or bunches of curled hair, not disposed in bands, either perfectly white or, when seen through haze, of a creamy or pale orange tint. Pure *Cirrus* is generally easily distinguishable in the daytime, as it is not disposed in rather slanting definite lines like *Cirro-filum*, does not extend into a broad horizontal sheet like *Cirro-velum*, and is very dissimilar to the rather rounded spots of *Cirro-macula*. Representations of this cloud are given in Plate V. and Illustration VI. Its altitude is very variable, as seen from Table III. (§ 25), but its average altitude is about 25,000 feet.

93. *Cirrus* is common in intra-tropical regions, but is not very abundant over the tropical calms. It is rarely seen over the interiors of the large continents, especially at the greatest distance from the leeward oceanic margins of the continents. It is not at all

[illegible]

[illegible]

processes, mentioned in § 89. It nearly always [illegible] slight curve, but the greater this curve the more [illegible] does the cloud approach the form of the variety *Cirro-*[illegible]. In fact, it may sometimes be difficult [illegible] whether the cloud is *Cirrus* or *Cirro-filum*, but [illegible] ty is merely one of nomenclature, as the [illegible] we gain from the observation of the amount [illegible] is independent of the name which we give to the cloud. At the same time, we must always remember, in estimating in our own minds the amount of twist, the effect that perspective will have. Thus if the cloud is moving towards or away from us, we shall not see so much of the curve as we should if it were moving across us. It will be seen that the sharper this curve the greater is the difference of velocities between the currents in which the cloud exists.

95. This latter fact may be shown as follows—Suppose that E is the position of the head of the cloud at any moment, and that it has been travelling in the direction AE with a uniform velocity represented by AB. Let the spaces between the equidistant horizontal lines (Figs. 5, 6) represent layers of air through which the particles are falling. Let the velocity of the current in each layer be uniform, and let the distances el, fi, gk, hm represent these velocities, so that el is the velocity of the top layer and hm that of the bottom layer. Also suppose that the particles are falling with a uniform velocity represented by Ae. Then the particle which started at A will now be found at a point a such that $ha = el + fi + gk + hm$. The particle which started one interval later, that is, from B, will be found at a point b such that $nb = el + fi + gk$; and so on. So that the shape of the whole cloud will at this moment be represented by the figure formed by joining the points a, b, c, d, E, or, more strictly, by a curve passing through these points. By a comparison of Fig. 5 and Fig. 6 we can see at once how rapidity of

[illegible] higher lati- [illegible] even when [illegible] summer "anti- [illegible]

[illegible] simplest type of inclination [illegible] complicated by

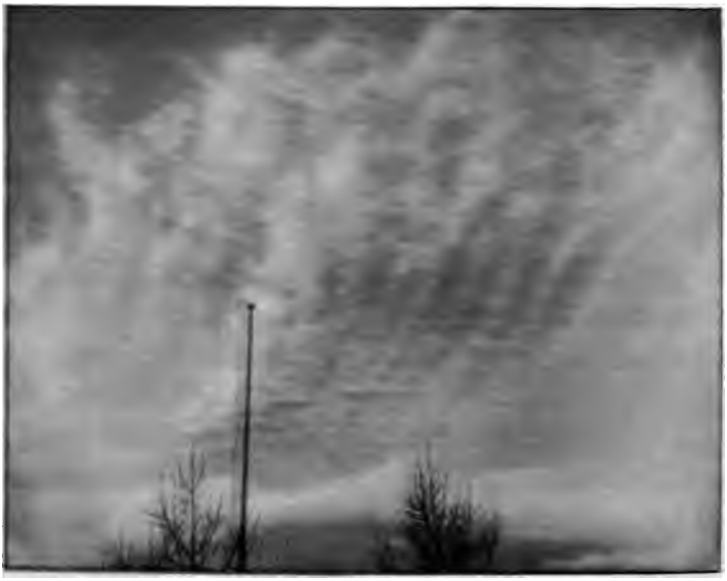
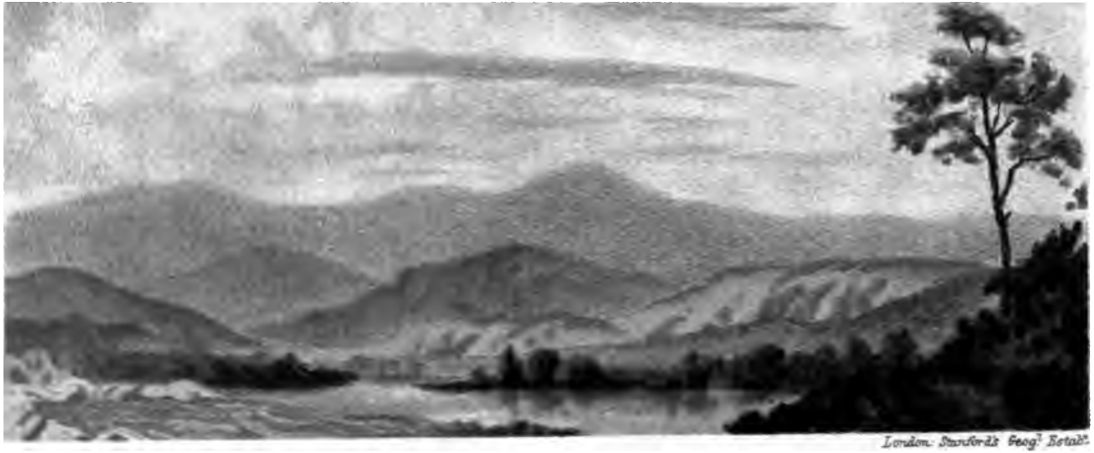


Photo by [illegible] *Esq.*

ILLUSTRATION VI.—CIRRUS.

other processes, mentioned in § 89. It nearly always has a slight curve, but the greater this curve the more nearly does the cloud approach the form of the variety *Cirro-filum*. In fact, it may sometimes be difficult to say whether the cloud is *Cirrus* or *Cirro-filum*, but this difficulty is merely one of nomenclature, as the knowledge we gain from the observation of the amount of [illegible] is independent of the name which we give



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CIRRUS WITH STRATUS LENTICULARIS

decrease in the velocities of the currents through which the particles fall affects the shape of the cloud. Of course the above method assumes uniform velocities, which is only true if we make our intervals of time indefinitely small. Now great difference of velocity always indicates disturbance of some kind in the atmospheric equilibrium. Hence simple *Cirrus*, which has very little slant, and hangs nearly vertically, is of itself by no means an indication of bad weather, but rather the opposite.

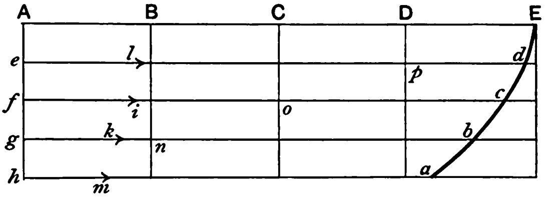


FIG. 5.—CURVED FORM OF CIRRUS.

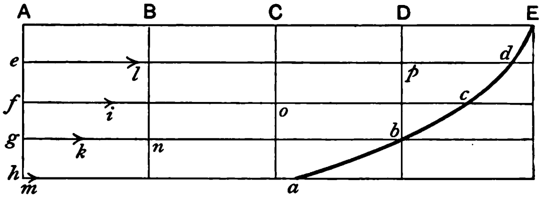
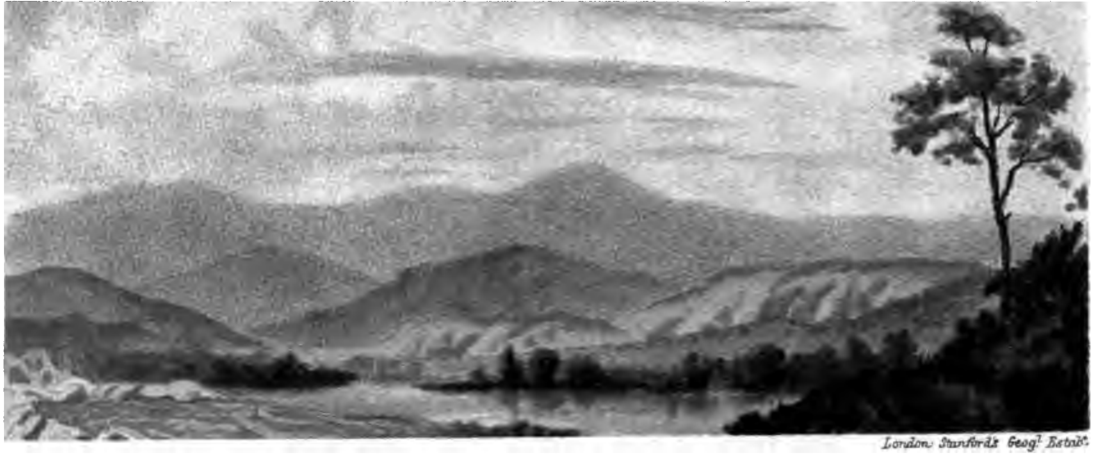


FIG. 6.—CURVED FORM OF CIRRO-FILUM.

The curved form of the brushed-out portion of a *Cumulo-nimbus* may be drawn in a similar manner to the above, but the particles being here emitted in an upward direction, the curve will be reversed.

96. The true detached *Cirrus*, which has no tendency to distribution in parallel bands, does not often either accompany or immediately precede



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CIRRUS WITH STRATUS LENTICULARIS

extensive atmospheric disturbance. It may, however, usually be taken as an indication of previous and often very distant local showers. In fine summer weather, with a rather high and steady atmospheric pressure, a local thunderstorm frequently leaves a mass of *Cirrus* in the sky, which may remain for two or more days suspended in the atmosphere, and might float for a distance of several hundred miles from the spot at which it originated.

97. The largest and most elevated *Cirrus* clouds being usually relics of distant thunderstorms, are most common in our latitudes in summer. *Cirrus*, however, is not uncommon in our winter season, and is often then an indication of more disturbed weather, because the *Cumulo-nimbi*, from which it is developed, are not present in winter except within or in the neighbourhood of cyclonic circulations of the lower atmosphere. Thus it is that if a sheet of low *Stratus Quietus*, a cloud eminently of the winter anticyclone, be observed to have far above it a little *Cirrus* or *Cirro-filum*, we must regard it with suspicion.

The velocity of simple *Cirrus* is generally much less than that of *Cirro-filum*, for whenever the velocity of the currents which carry the cloud is very great the ice particles arrange themselves "end-on" in bands or belts, and the cloud is then no longer simple *Cirrus*.

98. A few rough rules with regard to the influence of the direction of *Cirrus* on the weather experienced in the British Isles, although the laws on which they

depend have not yet been treated of, may perhaps here be useful and instructive.

Cirrus moving from N. or N.E. with a high barometer is a sign of settled weather in summer and of temporarily fine weather in winter. With a low barometer it is a sign of marked improvement in weather.

Cirrus moving from E., a rare occurrence, is a sign of fine weather in winter, but of unsettled weather in summer.

Cirrus moving from S.E. (but it rarely does so with a low and unsteady barometer) is a sign of improving weather in winter, and in summer frequently indicates coming thunderstorms.

Cirrus moving from S. is generally an indication of unsettled weather, especially in summer. The temperature is then usually above the mean for the time of year.

Cirrus from S.W. indicates unsettled and sometimes stormy weather in winter. In summer it often precedes thunderstorms, but with a high barometric pressure and a high temperature it frequently has no disturbing influence, and is then usually replaced by *Cirro-macula.*

Cirrus from W. is commonly in summer a symptom of fair weather, but it is less so in winter.

Cirrus from N.W., when not tending to the form *Cirro-filum,* is an indication of temporary fine weather, especially in summer.

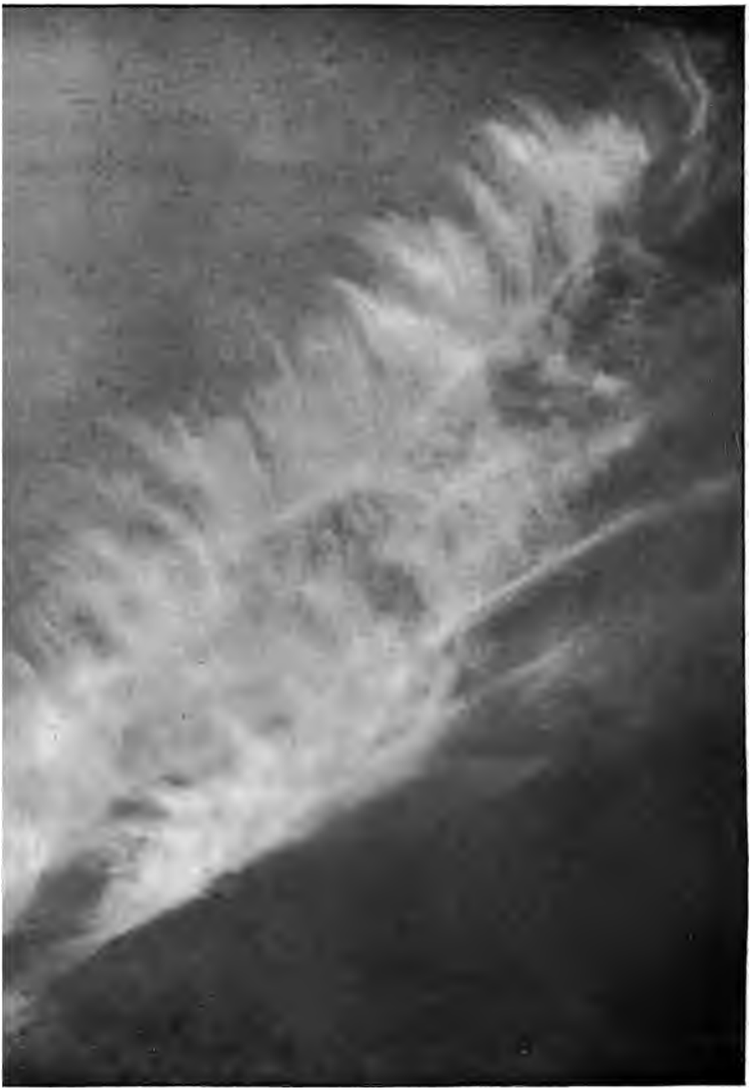


Photo by Arthur W. Clayden, Esq.

ILLUSTRATION VII.—CIRRO-FILUM SEEN NEAR THE ZENITH.

Cirro-filum

99. *Cirro-filum* is a thin, white, very lofty cloud resembling silky lines in the sky. These lines are very definite, and generally appear to have twisted or curled-up ends; they also generally arrange themselves in bands; in some instances, however, the cloud appears as a string of small separate wisps or feathers of cloud.

The cause of this twist has already been treated of in this chapter, and it will be evident from what has been stated that the straighter the whole wisp of cloud the greater is the velocity of the currents that carry it.

Cirro-filum, occurring as it does at an average altitude of 30,000 feet, moves generally with great velocity. Over the British Isles it is not an uncommon thing for the cloud to travel from N.W. in front of a disturbance with a velocity of 150 miles per hour. This velocity is more than twice that which is experienced, except in the most violent gales, in the lowest beds of the atmosphere, where the air is relatively dense and its motion is retarded by the inequalities of the earth's surface. But if straight bands of *Cirro-filum* occur at a comparatively low level, say 18,000 feet, we can immediately infer that the currents of the atmosphere at this level are moving much faster than they usually would. Similarly, if simple *Cirrus* were observed at the exceptional altitude of 40,000 feet, we should know that the currents here were moving slowly, perhaps abnormally so. The currents, however, of the region in which *Cirro-filum* exists are wider and less variable than those of lower regions.

100. The scientific study of the connection between the formation and movements of bands of *Cirro-filum* and sheets of *Cirro-velum*, and the probable distribution of atmospheric pressures at great altitudes, and the consequent character of approaching weather, constitutes a useful and fascinating field of research. It is, however, necessary in the first place that the observer should be able quickly to recognise the direction of movement of the cloud. Now *Cirro-filum* usually travels longitudinally, that is to say, in the direction of the lines of formation. But it occasionally has a slow transverse motion, *i.e.* a motion at right angles to the direction of the lines of formation. When this is noticed it is always, as might be expected, an indication of unsettled weather. For the current carrying the cloud must then be making a change of direction, whilst the cloud itself maintains for a short time its original shape. But the inexperienced observer is sure to labour under the erroneous impression that the threads of *Cirro-filum*, as also the exterior edge of a sheet of *Cirro-velum*, travel transversely very frequently. This impression arises from the fact that both the threads of *Cirro-filum* and the sheets of *Cirro-velum*, seen in the distance nearly parallel to the horizon, frequently propagate themselves rapidly towards the observer. Some experience is required for the determination of the movement of these clouds, and the observer who

has not acquired this confounds the direction of propagation with the direction of motion. Obviously the clouds can be all moving in a certain direction and yet be at the same time spreading out laterally.

101. The upward curl also of *Cirro-filum* is generally in front of the cloud in the direction in which it is travelling. But suppose the currents through which the particles of the cloud are falling to increase instead of decrease in velocity. This, of course, would be a rare occurrence, but the effect would be to reverse the cloud, and the upward curl would then be in rear of the straighter portion. Thus the position of this twisted end of the cloud, although very useful in helping us to conjecture the direction of movement when we have no time for the employment of surer means, as when it is only momentarily discernible through gaps of lower drifting cloud, is not a perfectly reliable method.

102. If belts of *Cirro-filum* pass through the observer's zenith as well as on either side of it, and the eye be directed longitudinally down them, they will appear to converge towards a point on the horizon. This point will be the direction from which the cloud is travelling, and is called the V point. When, however, as is more commonly the case, the belts of *Cirro-filum* do not pass through the observer's zenith, it will not be so simple a matter to find the V point. The belts will appear to form arches in the sky. A vertical line must be passed through the highest points of these apparent arches to the horizon, and the V point will be 90° from the

bearing of this point on the compass. Thus, if the highest point of the arches be E., and the cloud be moving from left to right, the V point will be N., and if the motion is from right to left, the V point will be S. If only a short thread of *Cirro-filum* be observed, we must make an imaginary arch for ourselves by pointing at the cloud and moving the hand briskly backwards and forwards in a curve in the direction in which the cloud appears to slant. From the highest point of this arch we can obtain the V point as before. There are generally, however, several other threads from which we can correct the V point thus found. It has been found, however, that the direction of movement of the cloud does not coincide with the V point; and from a great number of observations it has been shown that the average direction of movement is 15° to the *left* of the V point.

103. The V point cannot easily be determined if a little *Cirro-filum* is observed in the zenith and none else is visible. So seen the cloud is most commonly observed to consist of loosely disposed semi-transparent threads, often having small nubecules of ill-defined *Cirro-macula* attached to them. When the bands of *Cirro-filum* are well developed and their shortest diameter is considerable, the phenomenon of *cross-threads* is usually discernible in those bands which are closest to the zenith (see photo VI.). These cross-threads, which often give a ribbed appearance to the cloud, are transverse to the band, and care should be taken not to determine their V

point as the actual V point of the *Cirro-filum*, a mistake which can at once be avoided if there are any bands in other parts of the sky.

104. It will now perhaps be useful to give some rules for local forecast of weather from observation of the V point of *Cirro-filum*. The cloud in itself is generally an indication of unsettled weather, and the more rapid its movement the more unfavourable the prognosis. The following rules will be seen to be somewhat similar to those relating to the movements of simple *Cirrus*, and refer to those instances only in which *Cirro-filum* moves longitudinally; they should be studied in connection with the subject treated of in chap. ix.

1. A V point N. is commonly an indication of improving weather over and to the south of the district in which the observation is made, but of distant atmospheric disturbances in the N. and N.W.

2. A V point N.E. is an indication of temporarily settled weather, especially when it occurs with a high barometric pressure at the earth's surface.

3. A V point E. is a sign of settled weather in winter. In summer, especially when it occurs with high temperature, it sometimes indicates approaching disturbances, which will be felt most to the southward of the place of observation.

4. A V point S.E. indicates fine weather in winter, except when it occurs immediately after heavy rain, when it is commonly followed by squally weather. In summer it is almost invariably followed by thunderstorms with sultry and damp weather.

5. A V point S. precedes several classes of weather. When occurring with a fairly low barometer after a fall of rain it indicates showery weather in summer, and rough and squally weather in winter, with S.W. or W. winds, especially if the velocity of the cloud is great.

With a high barometer it indicates in summer thunderstorms approaching from the S.W., but in winter may be taken as a sign of favourable weather.

6. A V point S.W. is usually a sign of moderately fine weather.

7. A V point W. accompanies settled fine weather in the warmer months of the year. The weather in the S. and S.E. of the observer is then usually dry and warm, whilst that to the extreme N.W. is unsettled. In winter it is a symptom of unsettled weather.

8. A V point N.W. is a most unfavourable symptom, and when it occurs with or just after an increase of barometric pressure, is an indication of a sudden decrease of the same with rain and wind. A V point between W.N.W. and N.W., especially if the velocity of movement is great, is always followed by unsettled weather.

Cirro-velum

105. The cloud which we now have to notice is one which is closely related to *Cirro-filum*, and may be regarded as a further development of this cloud under slightly different conditions. *Cirro-velum*,

though not usually occurring at such great elevations as *Cirro-filum*, appears to consist of numerous interlacing threads of this cloud, which are so closely matted together as to form an almost uniform sheet. This sheet may be either so finely woven and so thin as to form an almost invisible veil of cloud, or may be comparatively thick and form a dense canopy covering a large area. The interlacing threads often give to the cloud a faintly reticulated appearance, and the under surface of a dense bank of the cloud is often combined with the higher forms of *Stratus*, which produce a streaked or speckled aspect. This under surface generally has an elevation between 14,000 and 30,000 feet.

106. It is difficult perhaps to understand how threads of *Cirro-filum* can become twisted together and interwoven so as to form *Cirro-velum*. For from what we know of the structure of the former clouds we should at first imagine it hardly possible for a number of threads to cross each other in a variety of different directions. But these threads are in reality superimposed upon one another at varying altitudes. *Cirro-velum*, in fact, although formed by the descent of ice particles, is a much more complicated form of Inclination cloud than either *Cirrus* or *Cirro-filum*. For in the formation of *Cirro-velum* the ice particles are met by currents not varying in velocity only, but also in direction. They are twisted and twirled about by these currents, and tend to become more separated and broken up, and to form a more even and shapeless mass. Nevertheless they

still retain, in a more or less degree, the structure of lines. But these currents which alter the general appearance of the cloud so much are too local to split the cloud up and carry its bits away in different directions. They are like the innumerable small eddies, currents, and ripples in a river, they seem to begin nowhere and to end nowhere, and yet the whole stream flows on in the same direction. The bank of cloud may appear to spread out and approach the observer, whilst in reality it is moving in quite a different direction.

107. From considering the conditions under which the cloud must exist, we are led to expect that banks of *Cirro-velum* occur in, or in close proximity to, those larger disturbances of the atmospheric equilibrium which bring with them periods of rainy and disagreeable weather. Whereas the bands of *Cirro-filum* are distant forerunners of these disturbances, the spreading sheet of the Veil cloud actually accompanies them.

108. As these banks can usually be seen from a great distance, and as most of our gales and nearly all our extensive and persistent rainfalls lie within them, it will be of great importance to recognise them as soon as they appear on the horizon. It is also worth noting that these great banks nearly always travel from a westerly to an easterly point in our latitudes. The advancing edge of such a bank appears as a curve in the sky, and the V point will consequently be 90° from the point of the compass occupied by the centre of the bank. The actual form

of the sheet of cloud as it appears when exhibited in a weather map is curved, but this curve is generally not discernible to an observer at a single station, requiring for its delineation simultaneous observations at places widely distant from each other.

109. The reader who has carefully studied what has been said about the movements of *Cirro-filum* will now perhaps be in a position to understand the following rule :—

When looking in a westerly or easterly direction, if the centre of the bank of *Cirro-velum* is to the right of the point from which the edge, or the *Cirro-filum* outside the edge, is moving, the probability of bad weather is not nearly so great as if this centre was to the left of this point. But looking in a northerly or southerly direction: if the centre lies to the right of the direction of motion of the edge of the bank, the ensuing weather will be worse than if it lies to the left.

110. As might be expected, the arrival of a bank of *Cirro-velum* is usually accompanied by a fall in the barometer, but it is also heralded by the total or partial disappearance of other forms of cloud in the sky, and even the haze produced by the smoke of large towns shows a marked tendency to diminish immediately before its approach. Thin lines of the higher forms of *Stratus*, especially *Stratus Lenticularis*, are, however, not uncommon immediately beneath the advancing sheet. When these move rather rapidly in nearly the same direction as the *Cirro-velum* itself there is some ground for antici-

pating that the canopy of ice-cloud will break up without producing very unsettled weather. When, however, they appear stationary, or nearly so, the prognosis is unfavourable.

111. In some rather rare instances the sheet of *Cirro-velum* is so thin and so evenly distributed that the particles do not seem to exist in any particular formation, and the whole sheet presents a faint milky appearance in the sky which may be only just discernible. This very fine and thin sheet is not common in the British Isles. It nearly always indicates the worst type of weather, for the very existence of a great shallow layer of ice-dust with no structural arrangement shows that the currents which carry it are too rapid and too variable to admit of such.

Such a sheet may, however, but on rare occasions, exist in actually fine weather in the early summer months. But it is much commoner in winter, when it generally moves from W. or N.W., and is immediately followed by *Nimbus*, and frequently by fresh and strong gales. It usually produces halos round the sun and moon, and this explains the idea that a halo round the moon is an unfavourable sign.

Cirro-velum Mammatum

112. On certain rather rare occasions the under surface of a sheet of *Cirro-velum* exhibits pendulous protuberances resembling sacks or bags of cloud, which produce a strange festooned appearance in the sky. This phenomenon is similar to that which has

already been noticed under the Tubercled clouds of Inversion, and is undoubtedly due to similar causes. These hanging festoons are the result of the vortex and wave actions of the process which we have termed Reversed Interfret, and the effect of this process at a high altitude in the currents which carry the ice-dust is similar to that produced in clouds consisting of water-particles.

113. The festoons or "pocks" of *Cirro-velum Mammatum* appear much smoother and more regular than those of lower clouds of Reversed Interfret. They always occur when the Veil cloud is moving above currents of colder air, and when it is at its lowest altitudes above the earth's surface. The circumstances under which such a phenomenon could occur are somewhat peculiar and interesting. They appear to me to be the following—Either the disturbance is moving across a surface, the air over which is colder than that over previous surfaces, or the disturbance is making a rapid change of movement, owing to some obstruction, such as an area of high land or of high pressure, or lastly, a secondary disturbance has arisen in close proximity to the first. From the above deductions we see that this cloud is deserving of the very closest attention by the observer, and it is a pity that its rarity has prevented a closer acquaintance. In any case, the cloud seems to be one indicating the very worst description of weather, and in this respect is in particular contrast with the other clouds of that most interesting process called Reversed Interfret.

Cirro-macula

114. A careful examination of *Cirro-filum* when seen in or near the zenith often shows it to possess a granulated structure, minute beads or flecks of cloud being scattered about and, as it were, powdered into the fine gossamer-like threads. When these nubecules appear to absorb the greater part of the threads, so that the whole congeries exhibits itself as a mass of small white specks of ice-cloud, we give to this form the title *Cirro-macula.*

115. This cloud is not common over the British Isles, although in some parts of the world it appears to predominate over the other clouds of Inclination. It has already been mentioned (§ 41) that it is often difficult to distinguish it from the higher forms of *Stratus Maculosus*, so very similar is its general appearance. From this similarity in form we cannot help being led to think that the same process must be at work in both. We know that the process of Interfret takes place in the higher currents of the atmosphere, and has a large share in the formation of clouds of Inclination. Now when this process takes place in very warm weather, in currents whose temperature increases rapidly with decrease in altitude, the whole formation of the cloud takes place throughout a vertical distance which is not very great, and the particles hardly fall any distance at all before being converted into vapour again. Thus the vortices caused by the Interfret process (§§ 10, 11) are the chief factors in the primary

condensation which start the formation of the cloud, although we may have the process of Inclination also at work. Hence an observer on the earth's surface will see both threads like those of *Cirrus* and of *Cirro-filum* and beads characteristic of *Stratus Maculosus.*

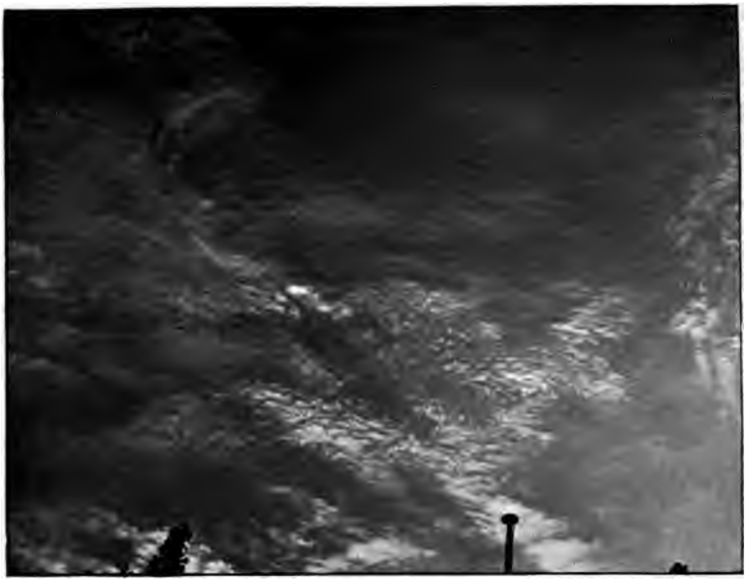


Photo by Arthur W. Clayden, Esq.

Illustration VIII.—Cirro-macula.

116. It may require some practice to distinguish *Cirro-macula* from this latter cloud, and the two clouds have always been confounded, even by experienced observers. It is only necessary to remember that *Cirro-macula* always consists of ice, and nearly always is combined with a few threads of ice-particles. Moreover, it usually exists at a greater elevation than *Stratus Maculosus,* and therefore its

proportions generally appear smaller and more delicate. Like all clouds of Inclination, it is much whiter and purer in tint, and does not present the light and shadow characteristic of lower clouds. It maintains, however, the arrangement in bands which appertains to *Cirro-filum*, and has therefore a V point, which is ascertained in the manner already described.

It will be evident from the above considerations as to the structure of the cloud that its weather indications are favourable. It nearly always occurs in warm weather when the atmosphere at the earth's surface has but little lateral motion. It sometimes occurs, however, in the rear of an advancing *Nimbus* when the sky is clearing of the composite form.

117. *Cirro-macula* is not at all a permanent cloud, and has a tendency to rapid evaporation. It is usually accompanied by some of the high clouds of Interfret which float in the layers of air immediately beneath, and often continue to exist long after its disappearance. The sky scenery thus formed is exquisite in beauty, but is not often seen in England. In fact, the higher the latitude the commoner are *Cirro-filum* and *Cirro-velum*, and the less common is the Speckle cloud.

CHAPTER VII

THEORY OF ATMOSPHERIC CURRENTS

118. It lies beyond the scope of the present work to deal in any but the most elementary way with those causes to which the complex atmospheric circulation prevailing over our earth is to be attributed. It is, however, needful here to describe, as briefly as possible, the general theory of the movements of the atmosphere, partly because cloud-structure is everywhere correlated with these movements, and partly because, although over all parts of the globe clouds are susceptible of a single classification, yet particular species of cloud are not everywhere due to exactly similar causes, and do not therefore accompany or presage similar weather.

Much of what will be stated in the present chapter has been thoroughly investigated by other writers, to whom the author's apologies are due. If the reader desires to understand the full investigation of the general circulation of the atmosphere he must refer to Ferrel's *Popular Treatise on the Winds.*

119. It will be convenient, in the first place, to neglect the effects produced by the rotation of the earth on its axis. We imagine, therefore, a fixed

globe, having a belt of high temperature, maintained by the sun revolving round it, as in the geocentric theory of the ancient astronomers, and having also two poles of relatively low temperature. If we suppose that this sphere is without water, and that therefore the air enveloping it is devoid of water-vapour, the superheated gases will expand over the thermal equator, and the chilled air will contract over the thermal poles. There will consequently be a head of air over the former region, and a meridional upper current will flow from this towards the latter regions, compensated by under currents from the poles towards the warm belt. There will be also a neutral surface between the two currents in which no horizontal movements will take place. Also the whole circulation would only take place in a downward and upward direction, and to and from the poles and the equator, were it not for the fact that diurnal heating and nocturnal cooling of the lower strata would give rise to slight displacements producing regular periodic westerly and easterly components of motion.

120. We will now consider the effects of the presence of water on this hypothetical sphere. In the first place, evaporation from water will lower the temperature of the surface from which it occurs, and of the air through which the water-vapour rises. Its next effect (§ 13) will be, in conjunction with dust particles, to render the temperature of the latter as well as that of the earth's surface more equable, by arresting the effects of solar and terrestrial radiation.

Its third effect will be observed in the condensation of vapour into cloud producing a rise of temperature in the surrounding air, and forming another screen for the strata of air below. Finally, precipitation, in the act of restoring to the earth some of the vapour previously withdrawn from it, will tend to decrease the temperature of the lower layers, and to check that state of unstable equilibrium (§ 5) which has preceded and accompanied condensation.

Looking now at these effects in their relation to the movements of the atmosphere, we see that they intensify the latter.

Condensation will obviously be greatest over the equatorial heat-belt, and this will tend still further to increase the head of air over this region, and therefore the velocities of the currents to and from the poles.

We have hitherto treated our hypothetical non-rotating sphere as being homogeneous. We will now consider the effect of placing two continents on this sphere. These continents may be regarded as circular, and each of about the size of Australia; one of these lies just to the north of the thermal equator, while the other is bisected by an arctic zone (Fig. 7). Owing to the different effect of solar radiation upon land and sea, the first-named continent will have an area on its southern side over which the temperature of the atmosphere will be higher than in the rest of the heat-belt. Also the arctic continent will have an area on its northern side colder than the remainder of the arctic zone, so that this area becomes the thermal pole. The effect of the positions of the two continents is shown in the figure, where the dotted arrows represent the upper currents and the firm arrows the lower currents. The lower currents will flow from the north of the arctic continent to the south of the equatorial continent, and the upper currents in the opposite directions. Precipitation also will be greatest over the equatorial continent, especially over its mountainous districts.

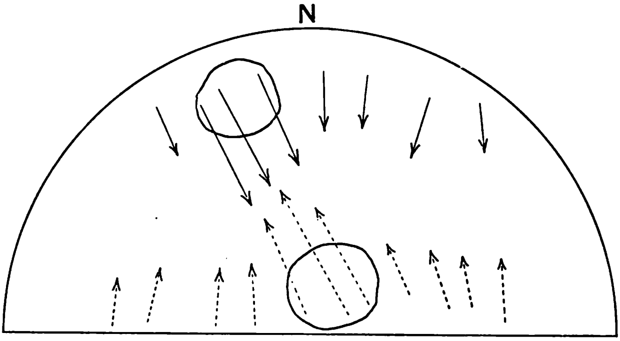


Fig. 7.—Without Rotation.

121. We now come to the effects on atmospheric currents of the rotation of that sphere upon which they move. It was recognised more than 150 years ago that the Trade Winds, which flow from the north-east in the northern and from the south-east in the southern hemisphere into the equatorial calm-belt, owe their relative westward components of motion to the fact that the earth is rotating from west to east. Hadley was the first to explain the relative westward motions of the Trade Winds, but certain errors of his were not entirely cleared away till the year 1859,

is a continuous flow from the equator to the pole. These currents are shown by the arrows in the figure, in which E is the equator and P the pole.

124. We will now consider the effect on the various currents by the introduction of two continents similar and similarly situated to those two we considered on a non-rotating sphere. As has been before seen, the northern continent will practically become the thermal pole, and the southern continent will be

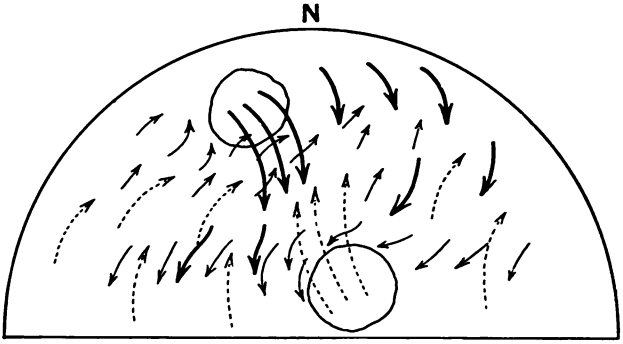


FIG. 9.—WITH ROTATION.

hotter than the rest of the equatorial belt. But the currents will not, as before, flow directly from one continent into the other. They will, as shown in Fig. 9, be deflected by the rotation of the earth. Thus the currents which flow towards the equator from the pole and from latitude 30° will be deflected counter-clockwise round the equatorial continent, and also sucked upwards, and there will be a permanent area within this continent of lower pressure at the earth's surface than would have been the case in a fixed sphere. Mountain ranges, as before, will increase condensation, and if they exist round the north-western, northern, and eastern edge of this continent they will act as obstacles to the winds at the earth's surface, and will thus still further decrease the pressure over the centre of this continent. The clouds over this area will be of the Inversion type in the warmer hours, and the higher clouds of Inclination and Interfret in the nocturnal cold hours. In the figure the lowest currents are represented by thin black arrows, the middle currents by firm black, and the upper currents by dotted black arrows.

Looking now at the arctic continent, we see that the currents in the highest and lowest strata of the air cannot pass directly into the area of denser air, but are deflected to the right by the rotation of the sphere, and tend to move clockwise round it. This increases the pressure at the earth's surface over the interior of the continent. The vapour-charged westerly winds which reach the southern coasts of the continent will precipitate some of their moisture as snow or rain. Should mountains exist of sufficient altitude, these will precipitate vapour from the upper currents. Moreover, if these mountains exist round the southern and south-eastern edge of the continent, by checking the eastward escape of the westerly winds at the earth's surface and the southerly outflow of the middle currents from the interior, the pressure of these lower and middle layers will be increased at this portion of the continent. Here we shall have "Interfret" action at no great elevation producing beds of *Stratus Quietus*.

125. We have not as yet considered the seasonal effects produced upon the atmosphere of our imaginary globe by annual changes in the sun's apparent path. These effects will be of a simple character.

Suppose the axis of this sphere to be inclined at an angle of 66° 32′ to the plane of its orbit. The sun will, of course, be vertical at different times of the year to all portions of the surface lying between latitudes 23° 28′ N. and 23° 28′ S. Over each of these latitudes, therefore, there will be a single summer solstice, while between them the sun will be vertical twice in the year. We shall therefore have two belts lying near each tropic, along which, so far as they are not interfered with by our supposed intra-tropical continent, there will be one season of the year marked by the greatest heat and the greatest amount of cloud and rain. When this belt is nearest to the northern tropic, the northern belt of high pressure which, as hitherto supposed, lay over latitude 30° N. will now lie much farther to the northward, and the corresponding belt in the southern hemisphere will lie nearer to the equator. A similar change will take place in these belts when the sun is nearly vertical over the southern tropic.

In the former season, which will be the summer of the northern hemisphere, the under currents, which blow from the south-east out of the southern belt of high pressure, will cross the equator, and, being deflected in the opposite direction in the northern hemisphere, will become south-westerly currents. Also, in the summer of the southern hemisphere, the north-easterly under currents blowing from the northern belt of high pressure will, after crossing the equator, be deflected to the left of their course, and become north-westerly currents.

To these seasonal winds, as they actually occur on the earth's surface, the name "Monsoons" is given. The upper currents of the atmosphere, flowing out of the shifting belt of low pressure, will, in crossing from one hemisphere to the other, move in directions the reverse, generally speaking, of those of the under currents. At and near the equator there will be a transit of the belt of low pressure twice in the year, and here there will be two rainy seasons separated from one another by the longest interval at the equator itself, whereas they immerge into one another so as to form a more prolonged season near the tropics.

126. Now, owing to the time occupied by the various heating processes taking place in the earth and its atmosphere, the maximum effects of solar radiation are not felt at the time when the sun's rays are most vertical. To this delay we give the title "Heat-lag." This heat-lag is noticeable at most localities on the earth's surface in the diurnal variation of temperature. The highest temperature is, on the average, experienced about two hours after noon, and the diurnal maximum of Inversion currents is reached generally between one hour and two hours and a half later still. Over fairly extensive oceanic surfaces between the latitudes 23° 28′ N. and 23° 28′ S. the maxima of the rains occur soon after the maxi-

mum temperature is attained. In the temperate zones the warmest week in the year occurs about one month after midsummer over low-lying land surfaces, whilst the coldest week in the year is about one month after midwinter. But at high altitudes and in high latitudes the annual heat-lag is much greater.

127. Before proceeding to touch upon the actual distribution of pressures and winds over the globe, it will be as well to summarise what has been stated in this chapter.

1. Convection currents over an imaginary fixed sphere, having a thermal equator and thermal poles, will, in the lower strata of the atmosphere, be directed from the poles towards the equator with a slight upward component, and in the upper strata will travel from the equator towards the poles with a slight downward component of motion.

2. The existence of vapour will modify and somewhat intensify such a circulation.

3. Land surfaces will displace the regions of thermal inequality, and therefore the atmospheric circulation between them.

4. Rotation of the sphere on its axis from west to east will cause bodies moving over its surface to be deflected, or to cause pressure, towards the right in the northern and towards the left in the southern hemisphere. There will be a belt of maximum pressure at the earth's surface at about latitude 30°, which equally divides the area of each hemisphere. From this belt the lower currents will flow from the north-east in the northern, and from the south-east

in the southern hemisphere into the equatorial calm-belt. Also from this belt, in the lowest strata of air, currents will flow from the south-west in the northern and from the north-west in the southern hemisphere, towards the polar calms. The upper currents will flow uniformly in directions parallel to these latter currents from the equator to the poles. These eastward deflections will diminish the atmospheric pressure near the poles and increase it in the direction of the equator.

5. Axial rotation will increase atmospheric pressure over continents in the higher latitudes and diminish it over continents in the lower.

6. Mountains will displace the centres of high and low atmospheric pressures.

7. Inclination of the sphere on its axis will displace the zone of highest temperature and alter all the atmospheric currents of the globe, causing the intra-tropical currents to cross the equator periodically and to be deflected in an opposite direction.

CHAPTER VIII

PREVAILING WINDS OF THE GLOBE

128. HAVING in the previous chapter dealt briefly with the theory of the subject of atmospheric currents, it will now be necessary to investigate some of the effects which the varied and complex distribution of land and water surfaces has upon the winds of the globe. It would be out of place in the present work to give any but a rough and brief consideration of such a vast subject, about which numerous works have been written by various authors. But so intimate is the connection between clouds and the winds which cause or are caused by them, that a description of the one would not be complete without some notice of the other.

The laws regulating the distribution of atmospheric pressures and currents already described must everywhere hold good. Over extensive oceanic surfaces the belt of equatorial low pressure round which the isothermal and isobaric surfaces are most elevated will resemble in the main the equatorial belt of our hypothetical sphere. Within this belt irregular squalls, due to local inversion currents, are interrupted by intervals of dead calm, forming a most undesirable region for sailing vessels. It is this belt which controls the general atmospheric pressures and currents of the globe, and it is for this reason that we must pay a closer attention to it.

129. The mean annual position of the equatorial calm-belt does not, as it would in a sphere covered with water, lie over the equator itself, but some degrees to the north of it in the two great oceans. This fact is well marked in the Atlantic, where it is only in the spring months of the northern hemisphere that the southern limit of the belt passes to the south of the equator. The cause of this phenomenon lies principally in the great frictional resistance experienced by the north-east Trades as compared with that encountered by the south-east Trades. Over these two oceans, therefore, the former never cross the equator, becoming north-westerly currents, as supposed in our hypothetical sphere. The annual oscillations of the belt are accurately known. It is most sharply defined over the greater part of the Atlantic and throughout the greater part of the year on its northern limit.

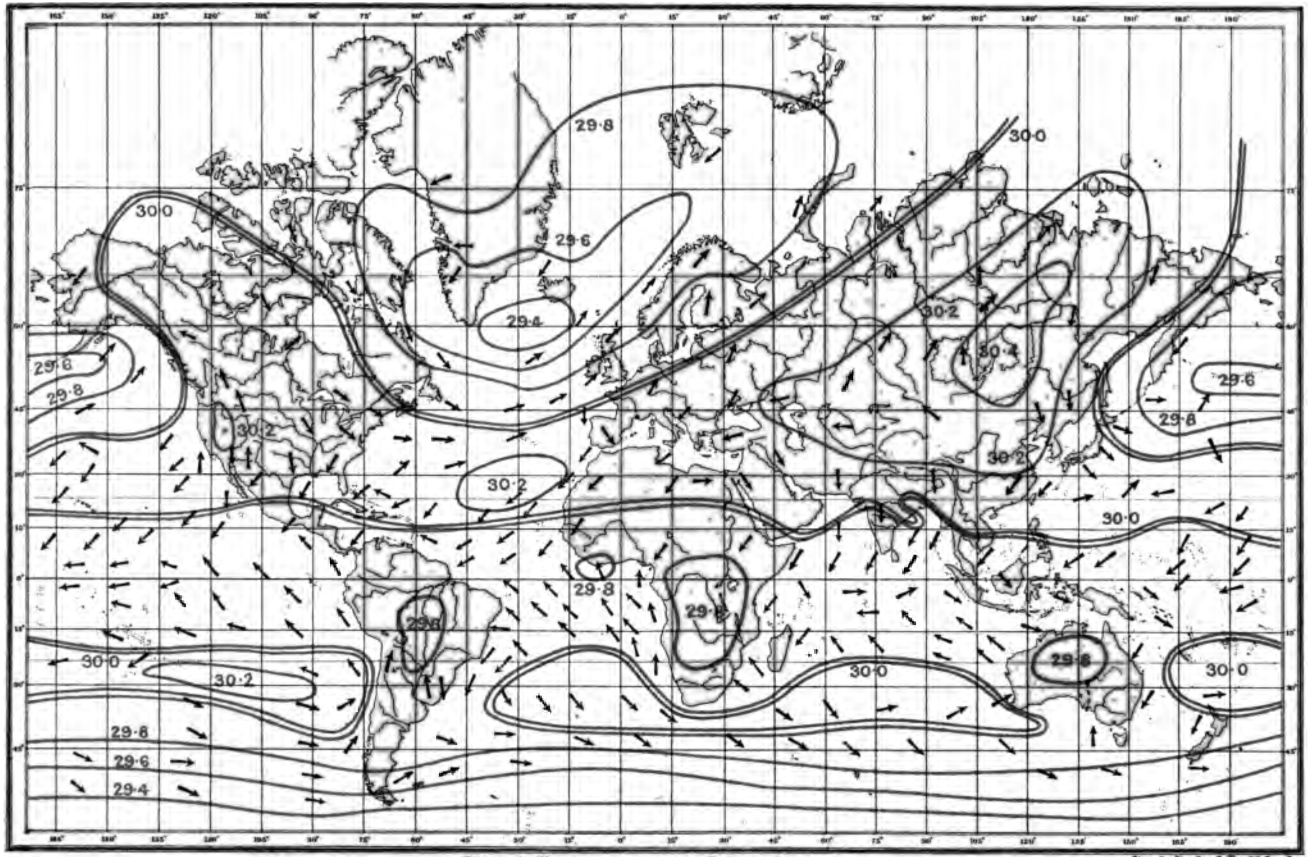
130. It will be convenient here briefly to describe the characteristics of the north-east and south-east Trades, which, over the oceans above mentioned, cover so extensive a surface. These currents, as we have already implied, tend to leave the surface of the sea when they approach the equatorial calm-belt; so that we frequently observe them carrying the exterior clouds of the belt over an atmosphere which is calm or irregularly disturbed on the ocean's surface. They also move somewhat more from the east at a slight

elevation than they do on the actual surface, a fact which is principally due to their tendency to rise, inasmuch as their upper portions, having travelled from the greatest distance, suffer the greatest deflection towards the west. The atmosphere throughout the Trade Winds has a very low relative humidity as compared with that of the equatorial belt, and in these, the great evaporating currents of the globe, it is felt as an invigorating and refreshing air. Over both the Atlantic and Pacific Oceans, but especially over the former, the south-east Trade blows with greater strength and persistence than the north-east, owing to the relatively small resistance of land surfaces.

131. It will now become most fitting to examine the principal effect upon the equatorial belt and upon the Trade Wind systems over the Atlantic and the eastern portions of the Pacific Ocean by extensive land-surfaces, before we proceed to consider the far vaster effect of the whole Asiatic continent upon the wind systems of the Indian Ocean and China Seas, and of the southern portion of that continent itself.

The reader who has studied the previous chapter will be prepared to find great tracts, in which atmospheric pressure is below that experienced in the oceanic equatorial belt, in the interior of the South African and South American continents. Round these areas the winds tend to blow clockwise wherever this motion is not checked by the interposition of lofty and continuous mountain chains. Such chains do not exist near the coasts of the African continent, and a glance at Chart I. shows that an area of pressure below 29·8

CHART SHOWING THE MEAN BAROMETRICAL PRESSURE & THE PREVAILING WINDS OF THE GLOBE FOR JANUARY.



Blue indicates pressures below 30 inches.

Stanford's Geogl Estabt London.

in. (757 mm.) at sea-level extends in January from about latitude 7° N. to latitude 25° S., following pretty closely the coast-line in its southern portion, while in the interior lies a nearly oval area of mean pressure below 29·7 in. (754·4 mm.). On the Gold Coast and in the Bight the winds consequently blow from south-west instead of from south-east and north-east; but they blow with great unsteadiness. This unsteadiness is partly due to the irregularity of pressure-distribution on this coast, as is shown on the chart for January. A small area of pressure below 29·8 (757 mm.) occupies Guinea, perhaps due to the resistance of the Cony range (although these hills are only between 2000 and 3000 feet in height) to the lower strata of the north-east winds blowing off the Sahara. But the irregular winds of the Gulf of Guinea are principally due to the great precipitation, especially in thunderstorms, which characterises this district. Here we have, in what would otherwise be the equatorial calm-belt, the deflected south-east Trade, which, having passed over a great oceanic surface, carries an unusual amount of vapour, commingling with air-currents from the north-east. We have therefore here, projecting from the African coast as its base into the Atlantic, a triangular area possessing the characteristics of the equatorial calms in an exaggerated degree. The climate is especially unfavourable to Europeans, and the navigator experiences oppressive calms frequently interrupted by violent squalls in different directions.

132. On the eastern coast of South America, at the same period of the year, we find a very similar

area of undesirable weather where the equatorial belt widens out and sultry calms alternate with heavy rainfall. Over the central and southern portions of South America there is an elongated oval of pressure below 29·8 in. (757 mm.), whose major axis lies nearly from the north-east to south-west, but this area is neither so extensive as that characterising South Africa, nor are its central barometric pressures so low. The winds which tend to blow clockwise around it are almost broken by the gigantic chain of the Andes, the largest chain of mountains in the world, which has nothing corresponding to it on the western coast of South Africa. On the north-eastern side of this area the Trades blow nearly from east, and in the valley of the Amazon, in particular, they penetrate as far as 60° W. longitude. Even at this season of the year the equatorial belt narrows towards the western portions both of the Atlantic and Pacific. The south-east Trades preserve to a great extent their direction, except very near to the eastern coast of South America and to the north-eastern coast of Australia. But the north-east Trades on the eastern sides of both oceans acquire a more northerly direction and an increase of force owing to the great areas of high barometric pressure occupying the greater part of North America and of Eastern Asia. The northerly winds in the Gulf of Mexico, the effect of the earth's deflection on which is checked by the land, often blow with great fury, attaining the force of the northerly storm which, as we shall hereafter see, also occupies the western side of the West Indian hurricane; the weather, however, accompanying the former winds belongs chiefly to the high-pressure systems.

133. It will now be convenient to turn our attention to the seasonal change which takes place in a system of winds belonging to the equatorial belt towards the commencement of the summer of the northern hemisphere over the Atlantic and Pacific.

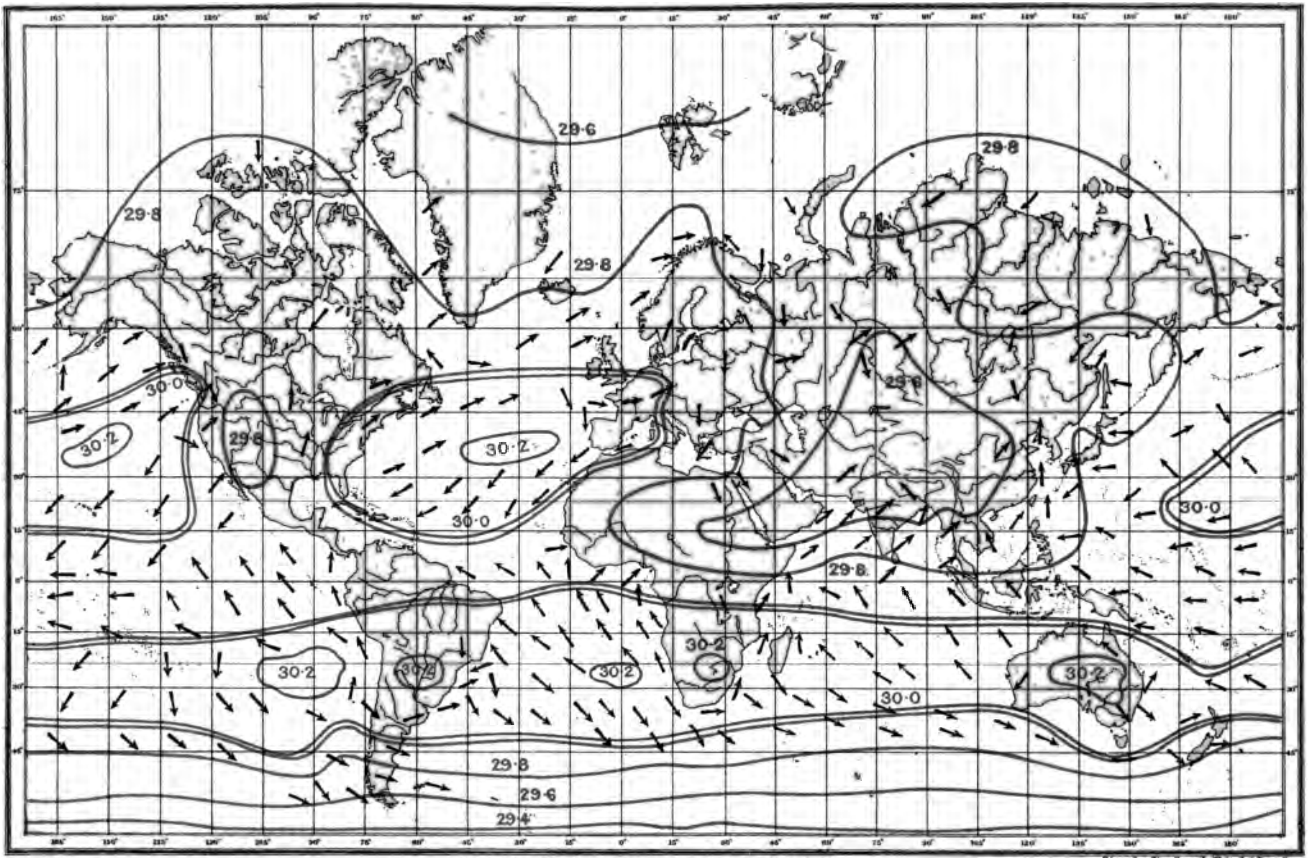
It has been already stated that on the Atlantic in the northern winter the north-east Trades scarcely anywhere cross the line owing to the great predominance of land in that hemisphere. A reference to Charts I. and II. will show that in mid-Atlantic no very great seasonal change in this system of winds occurs, but near the continents the changes are considerable.

South of the Congo the area of low pressure which characterised the summer season of South Africa has been replaced by an area of high pressure, while north of the line, farther to the north than even latitude 30°, a large area of relatively low pressure, which is in reality a westward extension of the still more remarkable area over the whole of Southern Asia, extends to the western coast-line, and some distance into the Atlantic off Cape Verd. On the northern and western sides of this area the winds under the influence of the earth's rotation move counter-clockwise, and are therefore experienced as north-easters in the northern portion of the Sahara, and as south-westers farther north than Sierra Leone, which station now experiences the detestable character of its wet season. Towards the eastern shores of America, on the other hand, the winds suffer deflection to the northward owing to the low-pressure area which now occupies the southern portion of the United States. This latter area is an elongated oval, whose greatest diameter lies north and south, and whose lowest barometric pressures occupy Utah and Arizona, a little to the south-east of the region occupied by the highest pressure in the northern winter.

In the Western Pacific what we have hitherto regarded as the equatorial calm-belt loses its characteristic position by widening out indefinitely to the northward for reasons which we shall presently revert to.

134. We have now to examine the equatorial system of winds between the Pacific and east coast of Africa, that is to say, over the China Seas, the Indian Ocean, the Arabian Sea, etc. In the summer of the southern hemisphere the northern belt of high pressure, which upon a globe of homogeneous surface should lie south of latitude 30°, and which actually does so over the Atlantic and Pacific, is joined to two great poleward extensions of high pressure, the one extending to the high northern latitudes of America, the other, of far vaster extent and intensity, over the Asiatic continent; see Chart I. This latter, with its corresponding low-pressure area in summer, may be regarded as *par excellence* the great "centre of atmospheric action" in our globe; next to which in importance follow the areas of low pressure occupying in the northern winter the

CHART SHOWING THE MEAN BAROMETRICAL PRESSURE & THE PREVAILING WINDS OF THE GLOBE FOR JULY.



Blue indicates pressures below 30 inches

Stanford's Geog^l. Estab^t. London.

northern portions of the Atlantic and Pacific Oceans. The effect of the Asiatic system of high pressure, together with the southward retirement of the equatorial belt, and also the low pressure now occupying the greater part of Australia, is to cause the north-east Trades to cross the line between the meridians of 90° and 165° east, and there to become, under the deflecting influence of rotation, a north-westerly wind. The rainy and tempestuous weather characteristic of the equatorial calms lies south of the line over this region during its summer season. Near the east coast of Africa, south of the line, the north-east Trades also cross the equator, becoming a north-west monsoon about the fiftieth eastern meridian; but the winds close to the coast, from the Gulf of Aden to the Mozambique Channel, are principally controlled by the great area of low pressure. The south-east Trade, wherever it exists throughout the South Indian Ocean, except where it enters the superheated belt, maintains the same characteristics as were noticeable over the Atlantic and Pacific Oceans.

135. In the spring months of the northern hemisphere a seasonal change is taking place throughout the Indian Ocean and the China Seas, to which no other seasonal change upon our globe is comparable, either in view of its extent or of its intensity. The high pressure which has characterised Central Asia is rapidly giving way under the increasing solar heat, the change being exceedingly marked over the southern part of the great continent as

soon as the sun has crossed the line. The heat-lag, which for the present prevents the south-east Trades from crossing the line, does not prevent the southern parts of the continent from acquiring a temperature higher than that of the adjacent ocean. Southern China, Thibet, Arabia, and India possess in May a very high temperature, accompanied for the time by an arid atmosphere. It is necessary here to allude to the well-known fact that, as regards the lower circulation of the atmosphere, India is practically cut off on the north by the wall of the Himalayas, and therefore has, both in winter and summer, a system of winds which is to a considerable extent peculiar to itself or idiopathic. It is, roughly speaking, about the time of the summer solstice of the northern hemisphere that the low pressure over the districts above mentioned becomes so marked that the south-east Trades cross the line and are deflected into south-westerly winds. The eastern portion of the vast current of air which is produced sweeps up the eastern coast of China, and is deflected counter-clockwise into the interior of the Asiatic continent. Farther westward another portion of it passes into Siam and Burmah, while on the eastern side of the Bay of Bengal the south-west monsoon which sweeps across the south of the promontory is deflected into a south-east wind near the mouth of the Ganges. The first inrush of the summer monsoon is, in India, frequently very sudden. As the thermal equator retires southward the summer monsoon, instead of dying out as suddenly as it began, gradually and intermittently breaks away throughout the whole of southern and eastern Asia, and the north-east monsoon of the northern hemisphere presently asserts its predominance, until we again reach in winter the conditions shown in Chart I.

136. In the summer of the southern hemisphere an irregular oval area, having barometric pressures below 29·8 in. (757 mm.), and having its longest axis in an east-west direction, exists over Central and Northern Australia. In the winter, on the other hand, an area of high pressure is noticeable over the more southern and south-eastern parts of this continent.

137. Looking now at the polar areas of depression, we find the south polar area to be fairly uniform, so far as observation extends, over all meridians. There is reason, however, to believe that in very high southern latitudes the gradients diminish in steepness; and some authors consider that there is a slight increase of pressure near the south pole. Although we regard the south-polar area of depression as practically uniform, centres of local depression course rapidly along this area from west to east, the winds shifting from north-west to south-west as they pass. Over certain meridians some of these depressions have a more northerly course, and the strong east winds of their southern segments are from time to time experienced. The north-polar depression is very greatly dislocated by the large amount of land surface in high latitudes, being almost interrupted where the two northern continents approach over Behring's Straits, and being thrown considerably to

the southward by an area of high pressure lying in winter over Greenland. This area is marked at this season of the year by the passage of local depressions, some of small, others of great dimensions, some of which sweep across the comparatively narrow continent of North America, while others are formed, and many expend their fury, on the North Atlantic and its coasts, a few travelling over Northern Europe and part of Northern Asia, but very few penetrating to any extent the great area of high pressure over Eastern Asia. It is principally the southern segments of these systems which are encountered on the steamship lines between Europe and America, the discomforts of whose south-west to north-west gales are only too well known to most readers.

138. The prevailing upper currents over the actual globe, while they follow somewhat more nearly than the surface winds the arrangement indicated in the previous chapter, are yet modified by the actual distribution of land and sea. For example, over the North Atlantic in winter the current which carries the highest visible clouds flows, with remarkable strength and persistency, from westerly points on the south side of the area of low pressure lying to the south and south-east of Greenland and Iceland, over somewhat lower latitudes than it would occupy over an ocean-covered sphere. The statement, however, that this current is permanently from the west—a statement which has been again and again repeated —is due to want of careful observation; for, as a matter of fact, the highest *Cirrus* is sometimes, though

rarely, noticeable moving from eastward points even in winter over North-western Europe and over Canada and the Northern States. Nevertheless, the slope of the gradients towards the pole in the higher regions of the atmosphere exercises so predominating an influence that even over Eastern Asia in winter the upper currents generally travel towards the east, not being governed by the great barometric maximum over the Asiatic continent. In an analogous manner over the northern segments of the non-periodic depressions of the higher latitudes the upper currents rarely move from any east point, and the effect of these depressions is, as we shall presently notice, to cause a southward inflexion of the lower isobars in the higher parts of the atmosphere.

Much has been written in recent years on the distribution of pressure at various heights in the atmosphere, and on the general slopes of the isobaric shells. A good deal of this is purely theoretical, and much is based on observations which are too sparsely distributed over the globe to be treated by us with full confidence at present. But even were it otherwise the subject does not apply in detail to the topic with which we are especially dealing in this volume.

CHAPTER IX

CYCLONES AND ANTICYCLONES AND THEIR CLOUD-FORMS

139. WHAT we have above regarded as the permanent and the periodic systems of atmospheric circulation represent the mean positions of the atmospheric pressures and wind-systems derived from observations taken during a number of years, and do not correspond with actual distributions of pressure and winds at any given moment of time. The variations from the mean, though considerable over intra-tropical regions, are much more distinct in the higher latitudes of the northern hemisphere, and they are somewhat more marked over the Atlantic and North Pacific. It is in these regions that the variable and intermittent systems generally come most distinctly into play, although in intra-tropical regions even more important irregularities are, at comparatively rare intervals, produced. It will be necessary to describe briefly the general characteristics of these local systems.

Cyclones

140. For our purposes a cyclone may be defined as any non-permanent area of low pressure into which

winds blow in a curved direction. It will be at once seen that such a definition embraces not only the small whirl and the large "depression," but also those more destructive and terrible occurrences, the violent hurricane and the tornado. Moreover, this definition takes no account of the origin of the centre of low pressure or of the weather usually accompanying it. Thus, as we shall presently see, a true cyclone, though generally of feeble dimensions, may occur without any particular formation of cloud or precipitation of rain.

141. Now from what has been said in the two previous chapters we know that round the permanent areas of low pressure on our globe the winds blow counter-clockwise in the northern and clockwise in the southern hemisphere. The reason for these motions is attributed to the rotation of the earth. For, if we have from any cause a centre of low pressure, the winds would blow from all sides directly into this area if the earth had no rotation (Fig. 7). But in the northern hemisphere, owing to the earth's rotation, and according to the law stated in § 121, the wind from the south will be deflected to the east of the centre of low pressure, the wind from the east will be deflected to the north, that from the north to the west, and that from the west to the south of this centre. Also, as we shall see when we come to speak of the origin of these cyclones, just as in the equatorial continent of our hypothetical sphere (Fig. 9), these winds will be sucked upwards as they approach the centre, and, rising higher and higher, they will eventu-

ally reach a level at which the isobaric surfaces are raised instead of being depressed, and they will flow out at a high level as upper currents. These upper currents, travelling with increased velocity, will spread away to a great distance from the actual disturbance, and it is the observation of these by means of the visible clouds which accompany them that gives us invaluable information of the movements of the distant cyclone.

142. The formation of cyclones used to be attributed to the collision of winds from different directions at the earth's surface, such as the south-west and north-east monsoons. That hypothesis must be at once set aside, for the reason that cyclones are primarily developed in areas where there has been immediately before their formation very little atmospheric movement, and barometric gradients which are almost insensible. More recently the formation of the cyclone has been attributed to a gyratory movement in very high layers of the atmosphere gradually propagated downwards to the surface of the earth. This theory must also be rejected, for, in the first place, it is not clear how such an upper current gyration could originate; in the second, no observation has ever indicated its existence; in the third, it has never been satisfactorily shown how, granting such an imaginary circulation, the eddy could work itself down through friction or viscosity against greatly increasing pressures to the surface of the earth. Moreover, above the barometric depressions which are primarily developed in extra-tropical

latitudes, observations of the upper clouds prove that in the higher surfaces of the atmosphere the isobars simply become hemicyclonic, showing an extension of the polar depression towards the tropic in the level of the *Cirrus* clouds.

143. Now it appears to us that as we owe all our varied permanent distribution of atmospheric pressure primarily to the effects of variations in temperature of different parts of the globe, so we must look for the true explanation of those moving areas of low pressure to a similar cause. And it will at once strike us that, even as in the case of the equatorial continent of the hypothetical sphere discussed in chapter vii., anything which tends to locally increase the temperature of the air at the earth's surface will tend to form an ascensional current, and therefore to decrease the pressure over that portion. Now we have seen (§ 8) that the greatest local ascensional currents are found when the process of condensation of water-vapour has begun to form an Inversion movement. This process, especially when it takes place on a large scale in an atmosphere in "unstable equilibrium" (§ 5), must produce a great diminution of pressure in the lower layers of air, and must therefore cause an inrush of air from all sides, which, as already explained, is obliged to flow round the centre and produce a cyclone.

We shall therefore expect that the largest as well as the most violent cyclones will originate over large water surfaces where evaporation and consequent Inversion movements are at their maximum. Dust particles also, in that they aid both evaporation and condensation, will help still further in the "brewing" of a cyclone.

The equator, where the effect of the earth's rotation is neutralised; countries where there are high mountain ranges interfering with the motion of the surface winds; the interiors of large continents, where there is little humidity; and, finally, the high-pressure belts over the great oceans, where there is a general downward motion of the atmosphere, and therefore a diminution of relative humidity in each mass of air as it approaches the surface of the globe—all these are regions from which the formation of true cyclones is excluded.

144. Although the production of a cyclone is ordinarily the effect of those Inversion movements which result from the extensive condensation of vapour first occurring in the lower and middle layers of the atmosphere, it cannot be assumed that cyclonic disturbance bears a very close relation to amount of precipitation. Not only does precipitation occur in very large amount, and that too over a large area, without much or any cyclonic disturbance near the floor of the atmosphere, but the fact must not be overlooked that feeble or shallow cyclonic action occasionally occurs over superheated land surfaces without any measurable precipitation at all. It will be evident that if the atmosphere over such land surfaces contains very little moisture, aided by dust particles, and in a state of unstable equilibrium, we may still have ascensional currents of some magnitude formed, and therefore the elements of a cyclone without the presence of vapour or cloud.

145. Having now dealt with the origin of cyclones, it will be necessary to say a few words on their propagation and its causes. The reader is probably already acquainted with the fact, mentioned in § 108, that the cyclones which cross our islands generally move in an easterly direction, and he will be quite ready to accept that this is due to the rotation of the earth. It will be as well, however, to give some definite reasons for this statement.

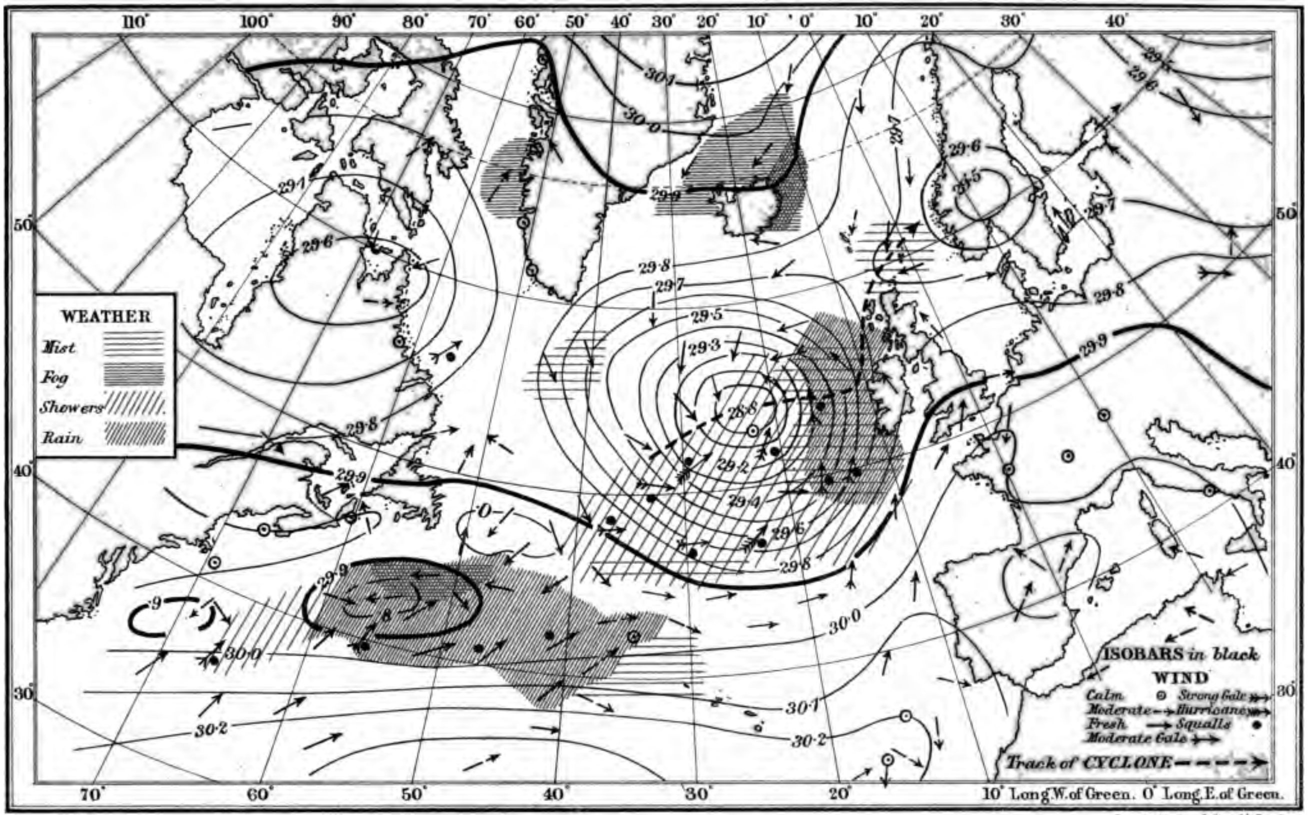
It has been found by Redfield that a cyclone which commences near the equator usually proceeds in a north-westerly or south-westerly direction (according to the hemisphere in which it exists), and curves gradually polewards until it reaches the tropical calm-belt, when the curvature becomes very sharp and it changes direction to the north-east or south-east, as the case may be, the whole curve resembling a parabola. Dealing with the reasons for this motion Professor Ferrel says :—

"The motion of the equatorial side of a cyclone in either hemisphere is always towards the east, and hence the deflecting force causes a pressure towards the equator, but that of the polar side being always toward the west, the deflecting force causes a pressure toward the pole. Now these deflecting forces being as the sine of the latitude . . . the pressure on the polar side toward the pole is greater than on the other side toward the equator, and hence the cyclone moves in the direction of the greatest pressure. It is not to be supposed, however, that there is an actual transfer of all the atmosphere of a cyclone from the equator to the polar regions. For the motions and pressure of the cyclone being greater on the polar side, where the deflecting forces which cause it are greatest, its action upon the atmosphere in advance of it is greater than on the equatorial side, where these forces are much less, and hence new portions of atmosphere are being continually brought into action on one side, while the resistance of the earth's surface and the adjacent portions of atmosphere on the other side are continually overcoming the comparatively weak forces there, and destroying the gyratory motion of the cyclone; so that the centre of the cyclone is being continually formed in advanced portions of the atmosphere. Since many cyclones are more than one thousand miles in diameter, the difference in the violence of its action on the two sides is very considerable. Hence the interior and most violent portion of a cyclone always gyrating from right to left in the northern hemisphere, and the contrary in the southern, must always gradually move towards the pole of the hemisphere on which it is. While it is between the equator and the tropical calm-belt it is carried westward by the general westward motion of the atmosphere there, but after passing the tropical calm-belt the general motion of the atmosphere carries it eastward, and hence the parabolic form of its route is the resultant of the general motions of the atmosphere, and of its gradual motion towards the pole" (*Popular Essays on the Movements of the Atmosphere*).

146. From consideration of the above it will not be a matter of surprise that the tropical cyclones move

CYCLONE OVER NORTH ATLANTIC, 10TH JULY 1883—GREENWICH NOON.

Chart III.



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more slowly and are of smaller dimensions than those of higher latitudes, but that they are, as a rule, of greater intensity. For the effect of rotation being less in low latitudes than in high, the distance from the centre of the disturbance to its edge will be much less.

It is not intended to imply that cyclones always move in the manner described above. Islands, continents, and mountain ranges, in conjunction with seasonal influences and those areas of high pressure called "anticyclones," these will greatly influence their movements. In fact, it is only the largest and the most rapidly moving ones that ever recurve eastwards and reach the higher latitudes. Moreover, many may have their origin in comparatively high latitudes, and many are simply offshoots from the intra-tropical disturbances.

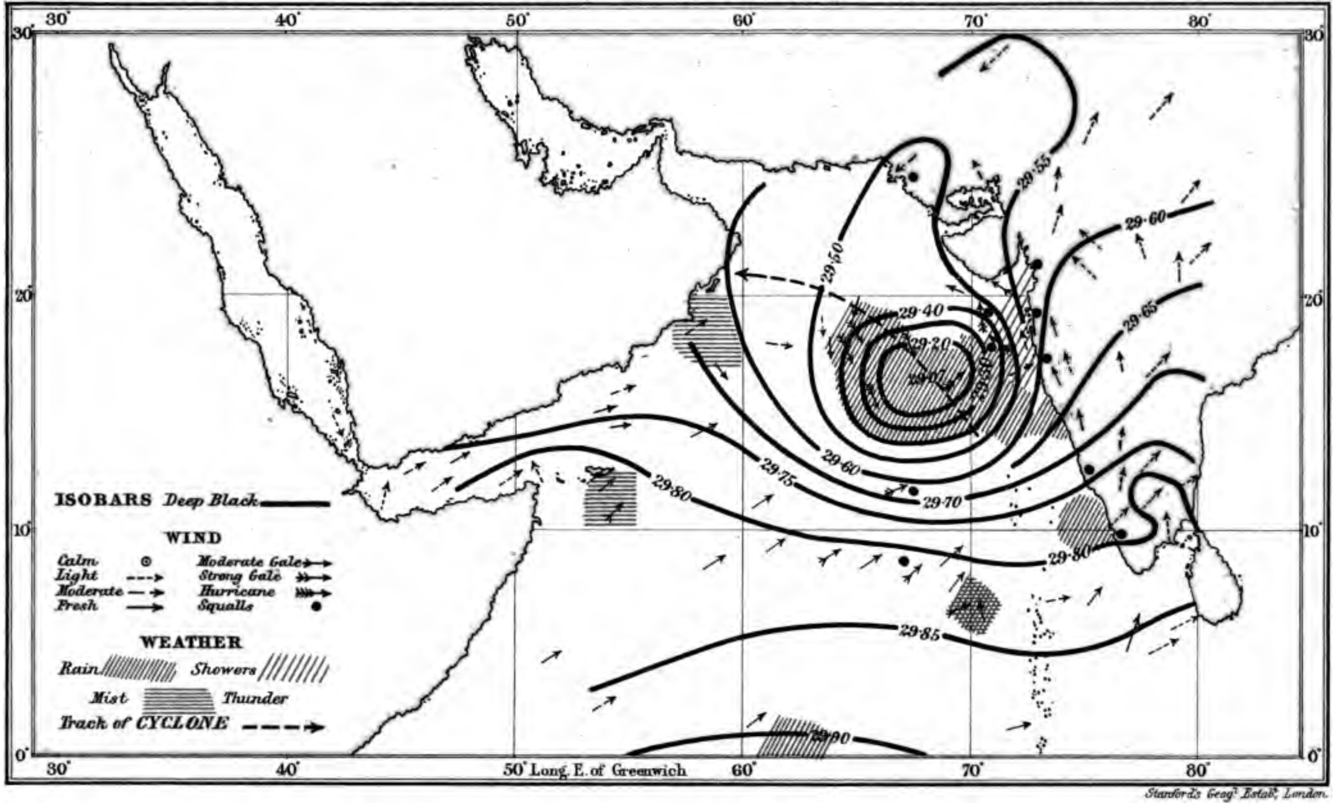
The laws which govern the translation of the cyclones of lower latitudes have been very extensively dealt with in many works treating of that subject. It need only be briefly stated here that since the diurnal oscillations of the barometer in lower latitudes have been perfectly well ascertained, any even trifling anomaly in the behaviour of the mercurial column, taken in conjunction with any unusual behaviour of the wind over those oceans which are, at the season of the year when cyclones are common, ever visited by these devastating circulations, requires to be carefully observed by the navigator. A great access to his knowledge, and a great addition to his security, will be made when the study of the cloud-forms in the neighbourhood of the intra-tropical cyclone has received the attention which it deserves.

147. The indraught of the lower winds into the central area of the cyclone of lower latitudes, while depending on the steepness of gradient and amount of frictional resistance presented by the earth's surface, is usually greater than the indraught into the cyclone of higher latitudes. Whether this indraught is greater in the front than in the rear of the disturbance, on the contrary, is a question which has not up to the present time been satisfactorily answered. The author inclines to the belief, which, however, requires confirmation, that the indraught is somewhat greater, or, in other words, the "angle of deviation" is somewhat less in the front than in the rear even of the cyclone of low latitudes. Above these cyclones the isobaric surfaces, greatly depressed near the floor of the atmosphere, are evidently considerably raised; and they are apparently more equally raised round all sides of the cyclone than is the case with similar systems in high latitudes. They seem, however, to be most raised in the front segments, since a brisk upper current usually flows off the disturbance in its front, an upper current which is of very great importance, in the relation to the cloud-forms which it carries, in enabling us to forecast the probable advance of the disturbance, more especially as the latter itself moves with a slow velocity of propagation.

148. With a view to illustrating the motions and characteristics of the cyclones of high and of low

CYCLONE OVER ARABIAN SEA, 9TH JUNE 1885 — 10 A.M. LOCAL TIME.

Chart IV.



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latitudes, I have selected two examples, one of which (Chart III.) occurred in July 1873 in the North Atlantic, and the available data for which were carefully worked out in *Synchronous Weather Charts of North Atlantic and Adjacent Continents.*

Chart IV. represents another cyclone which traversed the Arabian Sea in June 1885, and is derived from *Daily Weather Charts to illustrate the Tracks of Two Cyclones in the Arabian Sea.* This sea is much less frequently visited by these disturbances than the Bay of Bengal, and very much less so than the China Seas.

149. It has been already stated that some of the cyclones of higher latitudes are poleward extensions of those of lower. A great majority, however, of the cyclones which traverse the North Atlantic and Pacific, and a very great majority indeed of those which traverse the higher southern latitudes, are first developed on the poleward side of the tropical high-pressure belts. Their primary stage resembles closely that of the intra-tropical cyclones; that is to say, they are first formed over an area whose barometric gradients are slight, and where there is a humid state of the lower atmospheric strata. As a general rule, to which, however, there are exceptions, a young cyclone grows into existence in the rear of an old one, and it is partly for this reason that the cyclones of higher latitudes often follow one another for a considerable period along approximately similar tracks, and in rather regular sequence. When we consider the high velocity with which many of these systems

progress, we shall readily understand that a large portion of the air set in motion in each gyratory system fails to form part of the ascensional current within that system at all, and is left behind it in a state of temporary quiescence as this system passes on. When this portion of atmosphere has taken up much vapour from a moist surface, especially when it has come from warmer climates, it is in a condition of unstable equilibrium, which tends to the formation and maintenance of a new circulation.

150. The accompanying diagram (Fig. 10), representing the mean directions of upper and under currents round circular progressive cyclones over Western Europe, is taken from a paper by the author, published in 1877, and is derived from 2194 instances of upper currents observed in the different segments of such cyclones, and from 6396 observations of the calculated angles of the surface winds with the isobars at the earth's surface made in the same systems of circulation. In it the large arrow represents the trajectory of the whole system, the continuous small arrows the directions of the surface winds, and the dotted arrows those of the upper currents in the *Cirrus* regions of the atmosphere, the length of the arrows representing the relative velocities of the different currents. It will be observed, in the first place, that the incurvation of the surface winds towards the district of lowest pressure is far greatest in the front of these systems, while the outflow of the upper currents is also greatest in the front. This fact is, no doubt, to a great extent due

to the increased frictional resistance experienced by the currents near the floor of the atmosphere derived from the irregularities of the earth's surface, since the majority of the cyclones travel in an eastward direction and encounter irregular land surfaces on the east rather than on the west. Prof. Loomis arrived at an opposite conclusion with regard to the surface winds of the North American continent. Most of his observations were taken in the Eastern States, and therefore somewhat near the Atlantic coast, and in

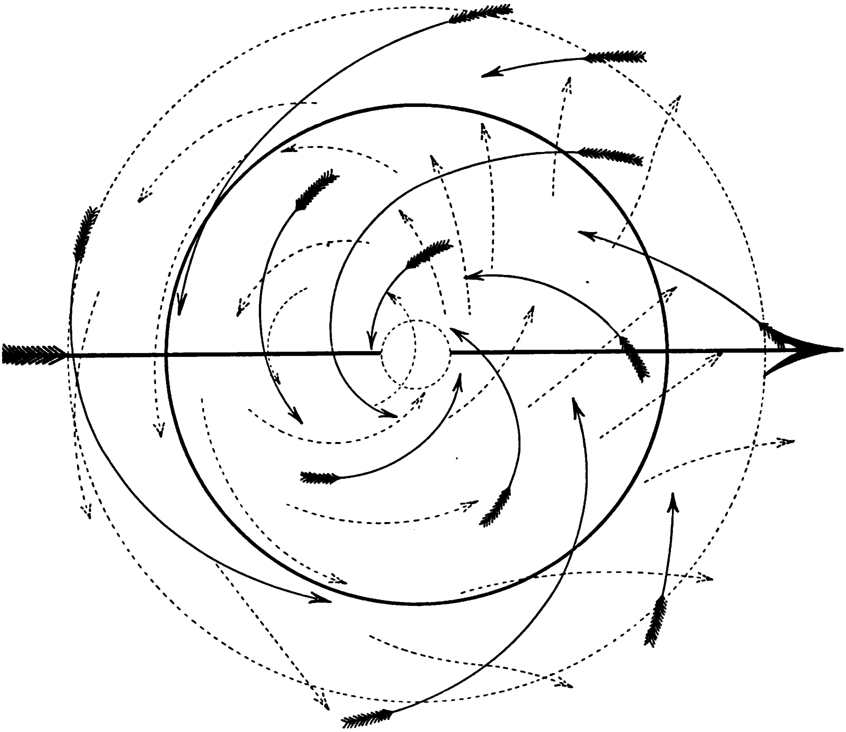


FIG. 10.—CURRENTS IN A TYPICAL CYCLONE. UPPER CURRENTS DOTTED ARROWS.

their motion over the sea these currents encounter less resistance than those on the western sides of the cyclones which have travelled over broad and irregular land surfaces. It may, however, be fairly regarded as certain that in the cyclones of the higher latitudes, at all events, the surface winds in front, which incurve toward the centre, are of less vertical thickness than those in the rear, and so far as this consideration is concerned, the former surface winds encounter more frictional resistance at some elevation above the earth than do the latter.

151. The upper currents over these circular progressive systems are far more rapid, as well as much more frequently observable, over the right-hand than over the left-hand segments; and in the extreme left of progressive cyclones reaching the shores of Western Europe these upper currents appear to be of small velocity and very variable in direction. This is, no doubt, due to the predominating influence of the general poleward gradient in the higher strata of the atmosphere; for just as the upper currents flow, generally speaking, toward the eastward over the eastern shores of Asia during the winter, in spite of the very high pressures prevailing at the earth's surface over the continent at this season, so in those cyclonic disturbances which are most perfect and of greatest vertical dimensions there is but little westward motion over the northern segments, the general tendency of the higher atmosphere continuing to be towards the east even here.

152. It is of much importance to observe in

relation to the above-mentioned fact that the predominating motion of a cyclonic disturbance in the higher latitudes coincides, roughly speaking, with the directions in which the whole system advances; and it may be further noticed that there is certainly a relation, though by no means of a very definite character, between the general velocity of the upper currents in the front and on the right hand of the cyclone and the velocity with which the whole system advances, in whatever direction it may happen to be travelling. We notice this in Europe, more especially in winter, and in those extensive and intense disturbances which sweep over portions of the North Atlantic during that season. In the summer of the northern hemisphere, both over oceanic and land surfaces, but more especially over the latter, cyclonic disturbances often exist at some elevation above the earth, apparently of considerable intensity, which are very faintly, and sometimes not at all, indicated by synchronous charts of the isobars and winds at the earth's surface. The explanation of this will become evident when we deal with the clouds which belong to these systems.

153. At first sight it would appear evident that the direction of progress of moving cyclones all over the globe is simply dependent upon the direction of the great upper currents, although we have been obliged to discard the idea that the primary development of the cyclone is itself due to an eddy in the upper currents. On the other hand, the direction taken by cyclones certainly bears an intimate relation

to the position of the great inversion movements, generally due to extensive condensation, which, in whatever direction the cyclone may be advancing, occurs principally in the front segments. In the circular depressions of the higher latitudes there evidently exists, as a study of Chart III. indicates, an elevation of the isobaric surfaces over the region of greatest condensation, and a depression of the same surfaces over the comparatively clear skies in the rear of the disturbance. And, on the whole, we may arrive at the conclusion, so far as our present knowledge extends, that the path of a cyclone is partly dependent upon the prevailing direction of the great upper currents, and partly upon forward propagation due to ascending movements on one side of the depression and descending movements on the other. How far one of these influences is superior to the other, and to what extent they mutually interact, must be at present left an open question.

154. It must not be supposed that the majority of the cyclones of the higher latitudes are actually circular. The predominating forms of the areas enclosed by the lower isobars are more or less oval, and in many cases there are complex systems in which several centres of low barometric pressure at the earth's surface are more or less contiguous to one another. Much the larger number of those circulations which travel eastwards over the North Atlantic and Pacific, and also near the Antarctic zone, present closed isobaric curves only over a small portion of their areas, and that on the side nearest the tropics;

on their polar sides the exterior isobars open outwards, so that there is an arm of higher barometric pressure at the earth's surface extending polewards between each system and its successor. To these arms such names as "coll," "ridge," etc., have been popularly applied; but, like the term depression itself, these words are as misleading as they are convenient, for over each poleward extension of high pressure at the earth's surface the isobaric shells in the higher regions of the atmosphere are depressed. Just as the majority of the cyclones of higher latitudes are seen on a synchronous chart as extensions from a larger system nearer the pole, so it is exceedingly common to observe over the tropical side of each cyclone smaller systems which appear as loops or inflexions of the isobars. Sometimes these smaller systems, which we call "secondaries," exhibit no closed isobars on the charts. They occasionally accompany a larger cyclone in its progress, sometimes they are left behind it, and in a slight majority of examples they travel on with greater rapidity than the original system, either disappearing in the areas of high barometric pressure at the earth's surface, or being developed into large and important systems by themselves. Some of the most intense and severe disturbances experienced over Western Europe originate in this way as offshoots from a larger cyclone in the North Atlantic.

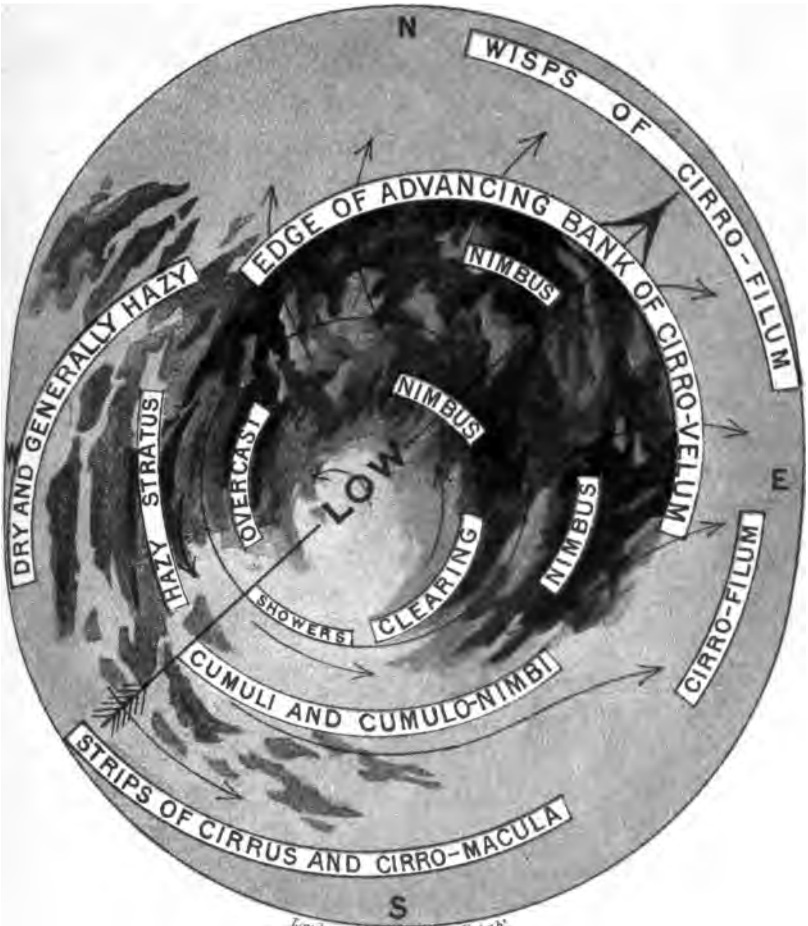
155. In all parts of the globe cyclonic disturbances tend to move round the more stable areas of high barometric pressures at the earth's surface,

leaving these areas on the right hand of their trajectory in the northern and on the left hand in the southern hemispheres. It is clear that the greatest supply of atmosphere thrown into rotation near the earth's surface must be derived from that region in which atmospheric pressures are greatest. But here again a relation which appears simple is in reality complex, since the rotating atmosphere of a cyclone tends, as previously shown, to increase barometric pressures at the earth's surface on the right of its course in the northern and on the left in the southern hemispheres, in whatever direction the system itself may be moving; so that the anti-cyclonic areas may be said to be as much determined by the cyclonic as the cyclonic are by the anti-cyclonic.

156. We now come to a subject of extreme importance to any one who wishes to put his knowledge of meteorology to practical use, and it is a subject which has hardly received the attention which it deserves.

In our description of the various kinds of cloud given in previous chapters we have, as far as possible, indicated the types of weather with which they are accompanied, and have in the case of clouds of Inclination given some practical rules for forecast of weather which do not presume a knowledge of the movements of those local systems of high and low pressure. It is these systems which practically constitute "weather" in its ordinary sense as distinct from "climate." A description of the climatic or,

Plate VI.



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CLOUD DISTRIBUTION IN A TYPICAL CYCLONE

generally, distribution of clouds is left to the next chapter.

157. Plate VI., which is derived from a diagram exhibited by the author in a lecture delivered before the Meteorological Society in 1878, represents the cloud distribution in a typical circular progressive cyclone. The large arrow represents the general direction of progression, and the smaller arrows show the direction of the upper currents. We have already learnt that the approach of such a cyclone is generally heralded by "outriders," consisting of wisps of *Cirro-filum* moving rapidly in the outflowing upper currents to the front and the right-front of the disturbance. These wisps may be more than one hundred miles in front of, but generally are closely followed by a sheet of *Cirro-velum*, which spreads over the front of the disturbance, and which is usually attached to clouds of Interfret and clouds of Inversion forming the great composite bank of cloud called *Nimbus* (§ 85), from which we generally get extensive precipitation. These clouds will, of course, appear to be moving in different directions, according to the different altitudes at which they exist, and to the position of the observer with regard to the disturbance. It will be seen by a study of Fig. 10 and of Plate VI. that the direction of the upper and under currents, and also the cloud-forms which accompany them, vary very much.

In the rear and to the right of the cyclone we find that there is generally a clearing up of the dense bank of *Nimbus*, and we get showers from local clouds of Inversion. Farther away still to the south and south-west we have strips of *Cirrus* which have been left behind by the distant storms accompanied by high *Stratus Maculosus* and *Cirro-macula.* To the west and north-west of the disturbance the sky does not clear so rapidly, but clouds of Inversion and Inclination are replaced by low clouds of Interfret.

158. The distribution of cloud given above is that of a typical cyclone. Of course, cyclones are not generally circular, and may not move in a north-easterly direction. Obstructions, such as mountains and large neighbouring areas of high pressure, may, and generally do, influence to a great extent the shape of its isobars and its general direction of motion. But the general relative distribution of cloud and wind will still be the same. For instance, suppose that we know from our daily weather maps or otherwise that a great anticyclone is lying on our west, and suppose that the wind is backing and veering between W.S.W. and N., and that we observe a distant bank of *Cirro-velum* in the N.W., travelling from N. or N.N.E.; bad weather is to be expected, a blustering westerly wind accompanied by a composite cloud-bank will probably veer to a cold N. or N.E. gale. On the other hand, under the same circumstances, let the bank be observed in the N.N.E. and travel from a northerly point, we are not then likely to experience more than a few slight showers of sleet or snow, with only a moderate backing and veering of the wind.

159. The typical cyclone illustrated above

belongs especially to high latitudes as distinct from one of those more intense disturbances which move in a westerly direction in tropical latitudes. As has been before remarked, evaporation from oceanic surfaces is much greater there than in higher latitudes, and thus the amount of condensation which takes place in a given volume of air is much greater, and therefore the heat given out much larger than is the case with the same volume in higher latitudes. The winds curving in towards the centre much more rapidly, the actual disturbance is more violent but more local. Electrical action also is stronger, the bank of *Nimbus* is thicker, and precipitation is far greater.

A peculiarity of these cyclones seems to be the absence of the clearing which we noticed in the typical northern cyclone to the rear and to the right of the centre. Ferrel observes, "In tropical cyclones the clouds are not driven ahead in advance of the cyclone," that is to say, not so exclusively as in the case of the cyclones of higher latitudes, "but there is enough of easterly current above in the cloud region to carry the clouds eastward to the rear of the cyclone, and consequently there is there 'overcast, damp, and frequently wet weather.'"

Anticyclones

160. The anticyclone may be regarded as the reciprocal of the cyclone in respect to conditions of atmospheric pressure at the earth's surface and the

motions of the air which characterise it. As we defined a cyclone so we may define an anticyclone as "any non-permanent area of high pressure out of which the winds tend to blow in a curved direction." In these pages, however, we confine the term "anticyclone" to those temporary systems of high barometric pressure which are approximately either circular or oval; and in thus treating the word as we employed the expression cyclone, we exclude some applications of it which are not without authority.

In the first place, we do not employ it of the more permanent areas of high pressure, such as that which occupies the greater part of the Asiatic continent in winter. It is true that this great system may be regarded as composed of a series of anticyclones which constantly merge into one another, but we could not call such an area an anticyclone any more than we should call the equatorial belt of low pressure a cyclone. Neither do we employ it of the belts of high barometric pressure near the tropics on the surface of the great oceans, for these also belong to the more permanent systems of atmospheric circulation.

In the second place, we cannot adapt it to the rings of relatively high pressure surrounding each cyclonic disturbance according to the use of the term as employed by Ferrel and some other authors.

Lastly, we do not classify as anticyclones the mere interspaces between adjacent progressive cyclones, which interspaces do not approximate to the circular or oval form.

161. As we have seen in chapter vii., if we have an area of high pressure, say one like the arctic continent of our hypothetical sphere, winds will tend to blow out of this towards neighbouring areas of lower pressure, and, in consequence of the earth's rotation, will be deflected clockwise in the northern and counter-clockwise in the southern hemisphere. Also if winds are blowing towards such a system, not being able to pass directly into it, they will be deflected round it and move in a similar manner. Cyclones also will be thus deflected and move clockwise round areas of high pressure in the northern hemisphere.

162. There are certain contrasts of the highest importance between the behaviour of cyclones and that of anticyclones. In the lower latitudes there are no distinctive anticyclonic systems corresponding to the hurricane or the typhoon. The anticyclone does not also appear to possess the same inherent tendency to travel eastwards as the cyclone in the higher latitudes, a fact which we must not too readily take as a measure of the degree in which the eastern movement of cyclones is due to propagation by condensation, and not to prevalent eastward upper currents. It is quite true that there is a tendency in the anticyclones of the higher latitudes to travel from west to east rather than in the opposite direction; and this tendency is most marked in those parts of the globe over which the cyclones travel for the most part with the greatest rapidity, *e.g.* over Canada and the Northern States. Nevertheless, the movement of anticyclones is occasionally, even over that region,

from some east to some west points; it is also extremely erratic; and, finally, anticyclones often remain nearly stationary for some days, or even for a considerable period. Since the movement of the cyclones is, as already mentioned, dependent in a large measure on the position of the anticyclones, it would be a matter of the very highest importance to ascertain the laws which determine the latter. Progress is being made in this research of a kind which is likely to prove of very high value both in relation to the theory of atmospheric movements and to the art of forecasting changes of wind and weather. It would be, however, premature and hazardous to enter into this speculation in the present place; and it must be sufficient to say that the formation and position of our anticyclones is apparently very intimately related to changes taking place in the intra-tropical regions of the atmosphere, changes which not only require a more extensive series of synchronous charts of pressures and winds at the earth's surface than we have until lately possessed, but demands still further far more careful investigations of the movements of upper currents on and between the belts of tropical high pressure. It is certain that over regions of the globe where barometric oscillations at the earth's surface are, generally speaking, slight, changes in the direction and velocity of the upper currents, chiefly due to changes of inversion in the neighbourhood of the equatorial calms, are by no means infrequent; and until these changes are better investigated, and the causes of them more thoroughly known, the task of calculating their effects upon the systems of atmospheric circulation in the higher latitudes must be left, however interesting, in the hands of the theorist.

163. In the same way as many of the cyclones of the higher latitudes may be regarded as extensions of the great systems of barometric depression at the poles, so many of our anticyclones may be regarded as offshoots from the belts of tropical calm, which become detached to some extent from the latter, and are developed in a poleward direction. But very many and important anticyclones have their birthplace in the higher latitudes, and possess systems of atmospheric circulation of their own, which appear independent of, and on their equatorial side are antagonistic to, the great currents which belong to the exterior of the tropical calm-belts. To a certain extent we can form some conclusion as to their formation at particular seasons of the year. For example, in the spring months of the northern hemisphere anticyclones are somewhat more common over the North Atlantic than at other times. It is at this season that over the more southern portions of the great continents of the northern hemisphere temperature is rapidly rising, while in the higher latitudes very low temperatures continue to exist at the earth's surface. The upward movement of atmosphere over the southern portions of the continents is thus accompanied with an increase of pressure in the direction of the poles; and it is to the anticyclones thus produced over the North Atlantic and over Northern Europe that the notorious character of the north-east surface winds in Western Europe,

which merit the title of the spring easterlies, is principally due. As our summer season approaches, insolation in the long days of the higher latitudes, by warming the floor of the atmosphere, raises the lower isobaric shells, and arrests the downward movement of the atmosphere over these regions. For the same reason, it is in the autumn of the northern hemisphere, when the temperature of the higher latitudes at the earth's surface is highest, that anticyclones over the North Atlantic and over Northern Europe are least numerous, and distinctly least permanent. The anticyclone is, however, a phenomenon which occurs at all seasons of the year in the higher latitudes.

164. These systems are, generally speaking, more characteristic of land than of ocean surfaces, for the very obvious reason that land surfaces have in winter a lower temperature than that of the ocean in their neighbourhood, and that the atmosphere on the ocean surface being more humid than that over the land, those extensive Inversion movements due to condensation of vapour which belong to the cyclone are much more prevalent over the oceans. Where these movements occur over land surfaces they are very frequently of the local type, which, while productive of violent showers and occasionally of tornadoes, are incapable of producing the larger cyclone.

165. As has been inferred, anticyclones are generally connected with a slow downward movement of the atmosphere, and the currents which flow out from them have not nearly the velocity of those rapid indraughts of air caused by a cyclone. The air in an

anticyclone being usually very dry, there is seldom a great quantity of cloud in an anticyclone, and the cloud-forms that do exist must be those which belong to slow horizontal or descending currents of the atmosphere.

166. In winter the anticyclone produces the sharpest frosts, owing to the absence of a vapour or cloud screen at night. A layer of *Stratus Quietus* in the daytime will effectually stop any of the feeble rays of the winter's sun from heating the cold earth below. This cloud is especially typical of the winter anticyclone, being a cloud of moderate Interfret, and generally requiring a downward motion of the atmosphere for its formation. As we shall see in the next chapter, it occurs everywhere where the atmosphere is settling quietly down, as in the interspaces between progressive cyclones, and as in the polar calms and areas of high pressure over large continents. It occurs, as already intimated, on the western edge of the typical cyclone shown in Plate VI.

Clouds of Radiation also are very common in anticyclones, especially at night-time and in winter (§ 27). In the hot weather of the summer anticyclone, *Stratus Quietus*, *Cumulo-rudimentum*, small *Cumulus*, and occasionally *Cumulo-stratus*, simple *Cirrus*, and perhaps a little *Cirro-macula*, are often seen, although the two latter are generally left in rear of a progressive cyclone. *Stratus Maculosus* also often exists on the exterior of an anticyclone, but not far from the outskirts of an area of low pressure.

CHAPTER X

PREVALENT CLOUD-FORMS OF THE GLOBE—PRACTICAL SUGGESTIONS

167. It would be an almost impossible task to describe in detail the cloud-forms of the globe, because the manifold effects of very varied distribution of land and water, in conjunction with seasonable changes, cause innumerable complications even over a small area such as that of Western Europe. All that can be attempted in this chapter will be to indicate very roughly a few of the general characteristics of cloud distribution. Any further detailed descriptions would serve no useful purpose.

168. We have already seen that for general purposes the globe may be divided into two polar areas, two wide belts of relatively high pressure traversing it in the middle latitudes, and an equatorial belt of reduced pressure. The belts of high pressure are the sources of supply of two great systems of winds — the Trades, which blow in a somewhat westerly direction towards the equatorial belt, and the anti-Trades, which blow in a somewhat easterly direction towards the polar areas. The whole system has a periodic variation dependent on the inclination

of the earth's surface to the sun, and it is further extremely interrupted by the relative position of land and sea surfaces during the different seasons. Where the equatorial belt crosses the two great oceans, the fluctuations of atmospheric pressure and the variations in the direction of the winds are comparatively unimportant, and it is here, and still more over the trade-wind regions to the north and south of this zone, that the cloud-forms observed are most permanent. Where, however, the seasonal distribution of pressure between the tropics is considerably modified by the seasonal heating and cooling of land areas, causing the Trades to cross the line and to form the periodic winds called monsoons, great alterations in the character of the clouds necessarily result.

169. Within the belts of high pressure which lie outside the region of the Trades the characteristic forms of cloud vary considerably as we proceed towards the poles, and as we advance into the region of the anti-Trades we encounter those great non-periodic fluctuations of pressure which are accompanied by non-periodic changes in the cloud-forms. These changes are least marked as we advance into the interior of the great continents, and it is in the middle latitudes of the latter that the greatest seasonal variation exists, and in the least interrupted manner, owing to long periods of heat and cold, which are the effect of the continued action of solar and terrestrial radiation. The non-periodic disturbances of pressure extend far into the polar regions, and even, we infer, to the poles themselves; but in these regions the

variability of the cloud-forms is greatly marked by the great diminution of solar heat, also by the diminution of the inequalities of terrestrial radiation due to the ice-covered or snow-clad surface of the soil, and to a still further extent by the small quantity of water-vapour contained in the atmosphere.

170. If we consider the causes which lead to instability in the atmosphere, it will be obvious to us that if the distribution of islands, continents, seas, mountains, lakes, marshes, and plateaux were fairly equable on the surface of our globe, clouds of Inversion would greatly predominate over the equatorial belt and all intra-tropical districts; for here the sun's heat is strongest, the vapour contained in the atmosphere is greatest in amount, and ascensional currents are naturally formed. Moreover, if we imagined that the great ocean currents did not exist, we should find it difficult to suppose that any great amount of vapour could pass poleward beyond the fiftieth or sixtieth parallel, or that Inversion clouds would occur on the polar sides of such latitudes. We should also be ready to admit that clouds of Inclination would be fairly common all over the globe, for the upper currents move much more uniformly and are much less influenced by geographical irregularities than those nearer to the earth. We should expect to find high clouds of Interfret also fairly common, but we should say that low clouds of Interfret could not occur in the equatorial belt or in the regions of the Trade Winds, because here both the middle and lower currents are flowing towards the

equator with ascending components of motion. But these latter clouds would occur over the tropical belt of high pressure and over the polar calms. We must now see how far these suppositions apply under the actual conditions prevalent over the globe.

171. It is an undoubted fact that clouds of Inversion increase more and more in frequency as we approach the warmer regions, and as a consequence of this we also notice that those clouds of Interfret which float at high elevations in the atmosphere are abundant over the same regions. For the upper currents, which pour away aloft out of the great areas in which extensive instabilities, and therefore extensive clouds of the *Nimbus* type, prevail, run off at considerable angles to the winds in the lower layers of the atmosphere, producing high clouds of intense Interfret in large quantity, especially during the nocturnal hours. Nevertheless, we have seen that over oceanic surfaces, especially at a distance from land, there is a remarkable equability both of temperature and humidity; also in the region of the Trades the winds are blowing from colder towards warmer latitudes, a condition adverse to Inversion movements.

172. It thus results that in the actual Trade Winds over the great oceans only two forms of cloud ordinarily prevail, viz. small scattered *Cumulus* and *Cumulo-rudimentum*, at no great altitude above the ocean surface. There are occasional strands of *Cirro-filum* whose form is regulated by the higher air currents flowing over the Trades out of the super-

heated belt. These clouds, which predominate in the Trades, both over the Atlantic and Pacific, are so well known as to have gained the title of *Trade Cumulus.* It may be asked why such clouds exist at all in the middle portion of the Trade-Wind region. The only reply that can be given is, that very slight inequalities of pressure and of wind with very slight inequalities of humidity, due to causes inappreciable to us, give rise here and there to small *Cumulus*, whose formation gives rise to further inequalities, and therefore to other local and unimportant Inversion currents.

173. We notice, however, the influence of land surfaces even at a great distance in a distinction between the *Cumulus* of the N.E. and that of the S.E. Trades over the Atlantic Ocean. In the former, especially in the higher latitudes over which it blows, there is much more cloud, and this cloud is much more irregularly dispersed. In the latter the clouds are comparatively few, and anything approaching a cloud-bank is of uncommon occurrence, this characteristic being obviously related to the relatively fickle character of the N.E. Trade in respect of force as compared with the S.E. Trade. It is noticeable that there is much less cloud as a whole over the Trade-Wind regions of the Pacific than over similar regions of the Atlantic. This absence of cloud is particularly conspicuous in the central part of the South Pacific over those parallels which are covered by the S.E. Trade, the sky in some parts of this region being almost perennially clear.

174. The fact, however, already stated, that the tendency to Inversion clouds becomes greater as we approach the equatorial belt, even at the greatest distance from land, still remains true. *Cumulus* becomes larger, and has loftier summits, until at last we enter the "cloud ring," as it has been termed, in which, as regards the atmosphere over the ocean, the true Inversion currents attain their climax. This belt is not a cloud ring in the proper sense of the word, since there is no continuous belt of clouds of any description. On the floor of the atmosphere calms alternate with strong gusts from different quarters, these latter being the horizontal components of the up-rushing and down-rushing currents of the atmosphere. Lofty *Cumulus* is rapidly converted into *Cumulo-nimbus* in the daytime, and not uncommonly in the night as well, while during the latter hours clouds of the Interfret type may frequently be observed at from 8000 to 18,000 feet above the sea. These are frequently superimposed upon each other, moving in different directions, often with considerable velocity, but in currents which extend to no very great distance. Where the Inversion currents happen to be somewhat extensive and large *Cumulo-nimbi* coalesce, true *Nimbus* frequently results; but in this case, as before observed (§ 143), no cyclonic disturbance can be generated, owing to the neutralisation of the effects of the earth's rotation, so long as the cloud-belt coincides with the geographical equator.

175. Proceeding poleward, we find towards the

exterior limit of the oceanic Trades an increasing deficiency in the amount of Inversion cloud, with a corresponding increase in the Interfret clouds of a low type. On the equatorial side of the tropical calm-belts *Stratus Quietus* is the predominant cloud. Over the Atlantic there is very much more of this cloud in the northern than in the southern hemisphere, for a reason already indicated. Near its southern limit it merges into irregular patches of *Nubes Informis* and *Cumulo-rudimentum,* which are often thick and massed together into a sort of local ill-formed *Nimbus,* similar in general appearance to that frequently seen in the non-periodic storms of higher latitudes, but forming no true commixture with any higher clouds, and therefore no Inversion movements of any importance.

176. Towards the poleward limit of the calm-belts over the Atlantic and Pacific, clouds of Inclination and Interfret largely predominate wherever these belts are not intruded upon by non-periodic circulations. These high clouds, which often produce beautiful sky scenery, are due to the overlapping of the strong westerly currents of the anti-Trades above the relatively calm atmosphere below. They are necessarily liable to variation in geographical extent according to the season of the year, extending polewards in the summer of each hemisphere. For example, in the North Atlantic during June, July, and August, when there is no permanent cyclone, as it has been called, that is to say, no long-continued series of cyclonic disturbances, between latitude 50°

and 65° N., the dappled skies produced by *Cirro-macula* and *Stratus Maculosus* extend much farther to the north, and also cover a much wider area, than in the winter months of the northern hemisphere. In this season cyclonic winds carve out, so to speak, large portions of the northern calm-belt, while anti-cyclonic systems, whose centres lie occasionally within the Arctic Zone, often show themselves on isobaric charts as united or welded into the high-pressure belt, both in the winter and the spring of the northern hemisphere. The characteristic cloud-forms of these two classes of accidental or non-periodic circulation have already been described, but the reader may be reminded that over the front portions of the cyclonic systems strands and sheets of clouds of Inclination largely prevail, while in their rear clouds of local Inversion predominate, and that over the anticylonic systems either clear skies or sheets of *Stratus Quietus* are noticeable.

As we approach nearer still to the poles, clouds of local Inversion become less numerous, and Inclination clouds, together with much *Nebula humilis*, more and more predominate.

177. If the earth, still possessed of an atmosphere such as it actually has, resembled the planet Jupiter in having its geographical equator always turned towards the sun, and if the disposition of land and sea were equable, the Trade Winds would never cross the equator, and monsoons would be impossible. In terrestrial conditions the existence of monsoons is very intimately connected with very important

changes in the equatorial cloud-belt. Roughly speaking, these changes may be said to be marked by a great accentuation, together with considerable augmentation of extent in the Inversion movements, noticeable where there are no monsoons over the equatorial belt. This accentuation is not due to the fact that the monsoons, being a continuation of the Trades, have traversed a greater distance of oceanic surface, and therefore carry with them more vapour, for in the case of the north-west monsoon of the South Indian Ocean such a circumstance is not true. It is rather due to the fact that around areas of Inversion clouds the rotation of the earth comes into play, preventing the immediate descent of masses of the air raised by condensation, thus extending the condensation areas themselves. In the areas of Inversion cloud into which the monsoons blow true *Nimbus* is far more frequent than over any region on the equator in the oceans of our globe. It is often very extensive, and the precipitation which takes place in it in excess of that which occurs in any other parts of our oceans. Between and around these areas *Cumulus* and *Cumulo-nimbus* (the latter, of course, frequently associated with severe squalls) are, considering that we are dealing with an ocean surface, often of imposing dimensions. Interfret cloud also frequently prevails, for reasons already explained, in considerable amount, and moving in very variable currents. Outside latitude 10° or thereabouts, at irregular intervals, and much more frequently in some seasons and in some localities than others, an extreme concentration of *Nimbus* is the precursor and accompaniment of the very rapid gyratory circulation known as the tropical cyclone, but under opposite conditions the belt of monsoon rains over the ocean is exceptionally narrow, quiet, or even interrupted.

178. We now come to the influence of islands upon the cloud-forms of our globe. That influence is most marked in the regions where the greatest Inversion currents occur, although, as previously observed, such islands as those which mark the northern portion of the west coast of Norway exhibit in summer the clouds of Inversion to a very marked degree. The superheating during the day of an island, even of small dimensions, lying near and within the tropics, yet outside the equatorial rain-belt, exhibits itself in the *Cumulus* which forms over it in the morning hours, portions of which float out seaward above the sea-breeze, and often in the *Cumulo-nimbus* which crowns the land in the afternoon at the time when convection reaches its climax, the summits of which spread but little over the sea, and, except where there is a somewhat strong predominant upper current, rarely produce rainfall on the sea-surface. Where the island rises in its interior into a lofty mountain this process is necessarily exaggerated. Perhaps the following description of an island lying in one of the sunniest and quietest portions of the globe will best illustrate the above-mentioned occurrence. Espy quotes the observations of Captain Williams made at Otaheite in 1815. "About 9 o'clock a cloud began to form around the

lofty conical mountain in that island, in the form of a ring . . . ., and it soon began to rain in torrents, and continued through the day. In the evening the sea-breeze died away, and the rain ceased, and the clouds soon disappeared, and it remained entirely clear till after the sea-breeze set in the next morning. . . . I was particularly struck with the phenomenon of the cloud surrounding the mountain when none was ever seen in any other part of the sky, and none there till after the sea-breeze set in in the morning. . . . The mountain stood in bold relief, and from where the ship lay its top could always be seen above the cloud, even when it was densest and blackest, with the lightning flashing and the thunder rolling, as it did every day. I passed up through the cloud once, and I know therefore how heavily it rains, especially at the lower side of the cloud. This rain never extends beyond the base of the mountain, and all around there is eternally a cloudless sky."

179. The highland of islands, promontories, and projecting portions of continental coasts, and, above all, mountain ranges lying in these positions, produce most abundant *Cumulus*, *Cumulo-nimbus*, and *Nimbus*, wherever these conditions meet the great currents of the monsoons, the Inversion currents being in such positions mechanically assisted to the utmost extent by the elevations in the floor of the atmosphere. During the prevalence of the monsoon these cloud-forms are rapidly dissipated on the leeward side of the island or mountain range. In an island or belt of mountains, which lies across the N.E. and S.W.

monsoons, the formation of clouds of the Inversion type changes seasonally from one side of the mountain or island to the other, but it by no means follows that the amount of Inversion cloud on the one side bears anything like the same relation to that on the other, which it would do if it depended on the length of the reign of each monsoon.

180. The geographical character of the whole area out of which the monsoon flows is the principal determining factor of the amount of Inversion clouds produced. For example, in Ceylon, which lies very nearly, if not quite, across the monsoons, the S.W. monsoon produces almost perpetual *Cumulus* and *Cumulo-nimbus* over the S.W. of the island, bringing a very abundant supply of moisture from the whole of the South Indian Ocean, but the clouds carried by this current, descending under increased pressure in the northern part of the island, are to a great extent evaporated; and, so far as the general current is not interfered with by the land and sea breezes, the *Cumuliform* clouds are on this side much more sparsely distributed. The N.E. Trade blows over an ocean area which is relatively extremely small, to the north of which lie elevated mountain ranges, and beyond these the vast and arid plateau of Central Asia. Consequently, the *Cumuliform* clouds produced by the blowing of this latter Trade over the island are of a relatively unimportant character. To take an opposite example on a larger scale on the southern side of the equator, the whole of the northern portion of New Guinea is the habitat during the rainy season

of Inversion clouds of great extent and dimensions. But these clouds move mainly in the N.E. Trade, which becomes a N.W. monsoon to a certain extent over the interior of this great island. During the period of the year when the belt of greatest heat is transferred to the north of the line the S.E. Trades produce *Cumulo-nimbus* and *Nimbus* over the southern half of the island; but not having traversed nearly so great an extent of ocean surface, and having only recently left the southern tropical calm-belt, their influence here in producing clouds of Inversion is similar to that which prevails on the northern and north-eastern portion of the neighbouring continent of Australia.

181. The steepness of the coast-line and the abruptness of a mountain range facing the prevalent wind exercise great effects on the formation of Inversion clouds. A very familiar example, familiar not so much from observation of the cloud-forms as from the precipitation unequalled on any other locality, well known to Europeans, is to be found in the Khasian Hills. The altitude of Cherapongee is only 4455 feet above tide-level. Here the winds during the period from April to December blow directly from the Bay of Bengal and from the Indian Ocean beyond it against the face of a steep acclivity, without traversing at this season (as is the case with those winds which meet the Himalayan range) any extensive portion of the Great Indian Peninsula, itself now drenched at frequent intervals by *Nimbus* and *Cumulo-nimbus*. Here, therefore, the clouds of

Inversion are almost incessant. They are generally in the form of a *Nimbus* during the height of the monsoon, which is in June and July. In the preceding and two succeeding months *Cumulo-nimbus* prevails here nearly as frequently as *Nimbus*. It is well known that the mean annual rainfall at this station is 475 inches, nearly all of which falls in the summer months. The southerly winds blowing over this range into the great heated plateau of Southern Asia are almost completely denuded of cloud-forms in their passage, and on the leeward side flecks of *Cumulo-rudimentum*, together with a very small amount of clouds of the Inclination and Interfret types, are commonly all that are to be seen in the sky during this season of the year.

182. The influence of somewhat elevated coast-lines in intensifying monsoon rainfalls is noticeable in a less degree on the west coast of Africa north of the line, where south-westerly winds prevail during the summer of the northern hemisphere, producing *Nimbus* and *Cumulo-nimbus* along the coast and a little way into the interior, together with much cloud of the Interfret type. Similarly, on the Isthmus of Panama a westerly wind blows from the Pacific in the summer, forming clouds of similar descriptions in abundant quantity.

183. Where a mountain range exists on the leeward side of an extensive land surface, that surface being of itself of comparatively slight elevation, abundant *Nimbus* and *Cumulo-nimbus* may be produced over the whole of the land surface by winds

bringing a sufficient supply of aqueous vapour from the ocean; yet clouds of these descriptions may be greatly intensified on reaching the mountain range. A specimen of this occurrence on a grand scale is found over the greater part of the South American continent, roughly, between the parallels of 30° S. and the equator, which presents in effect a vast southward extension of the equatorial rain-belt. All the basins of the Amazon, the Paraguay, and their tributaries are supplied with abundant cloud-forms of the Inversion types during the south-east Trade, which, over the northern portion of this area, is permanent throughout the year. *Cumulo-nimbus* and *Cumulus* are the prevailing cloud-forms over a great part of this area, but, as we proceed farther up the rivers towards the vast watershed of the Andes, extensive *Nimbus* becomes more prevalent, and on the eastern slope of this great chain of mountains, north of about parallel 20° S., is almost perennial. For this very reason, on the leeward or western side of the Andes, there is a large though narrow district where very little cloud is noticeable, that portion of the atmosphere which has traversed the range descending here towards the Pacific coast, under conditions which are most unfavourable to the production of clouds of Inversion.

Practical Suggestions

184. All said then, and done, the land of clouds is not entirely one of fancy. The art of distinguishing and of usefully employing the distinctions between the varieties of cloud is not nearly so difficult as many an art in which the amateur engages himself for the sake of amusement; and a very cursory acquaintance with the labours of many writers—especially, if it is not invidious to say this, of German and American writers—satisfies every one as to the fact that there is also a science of Nephology, nascent though this science may be. How can practice and knowledge be most successfully promoted?

To say that it is a mistake to make suggestions for which (however useful they may be) the times are not yet fit is to say an idle word. Our object, whether or not an individual in any degree attains it, should certainly be to lay down the materials for a road, where commerce calls for the undertaking, and to leave that road to be hardened by traffic, and utilised for further traffic. Results follow inevitably.

185. First, then, as to cloud charts.

As regards telegraphy, the task of devising the cheapest and most advantageous codes is so very easy, and so attractive, that it will be scarcely pertinent to attempt it here; and it seems almost a waste of time to dwell much upon any system of codes by which observations of clouds, as of most other meteorological elements, can be transmitted to a

central bureau from the stations where the observations are taken. It is enough to remark that, for the present, as soon as ever some classification is sufficiently crystallised, each variety of cloud can be conveniently represented by a digit, the digits can be arranged in groups (*e.g.* in groups of five), and the position of each digit in each group can of course be made clearly significant. Groups can then be wired as words, and what is more technically called "cipher" can be avoided. This has long been done in civilised countries, though in least measure with reference to observations of clouds, and done with entire success.

186. Now as to the mode in which the results of information acquired with regard to meteorological elements can be transmitted from a central office to those parts of the country which stand in need of these results, differences of opinion must exist, and the writer can but state his own opinion, *valeat quantum.* To him what is wanted seems to be, to decentralise the work to be done as speedily as possible. The venous circulation is in fairly good order, let the arterial be attended to. We are doing this in nearly everything, why not do it in reference to weather? I fail to see why every man should not be made his own "weather-prophet," a great and quiet constitutional change be effected in the self-training of the seaman and of the agriculturist, responsibility and pressure at the central office be relieved, and money at the same time be greatly economised, although any government which sanctions the task, or any nation

which carries it out, must be prepared for a trivial outlay at the beginning. Let a set of typical weather charts for each distribution of elements, showing isobars, winds (if needful), and weather, including cloud-forms and upper currents, be prepared. In the case of the British Isles, where, however, this kind of work is not very likely, owing to our economy and our conservative instincts, to be first begun, I find that 999 typical charts would be very considerably more than are needful. In some other countries the number would not be nearly so great. Let each chart be numbered and printed on the left page of a large book, and on the opposite page let a short description of probabilities of general changes be given in reference, more especially, to the season of the year. This task is simply nothing, and hundreds of men would do it with avidity and ability. Let the country sanction cheap transmission, *e.g.* the transmission, at present, of one group of three figures for the sum of the English twopence. Let every mercantile office at every seaport, every rural post-office, every club, which chooses to go to the slight expense, be supplied with a copy of this chart-book. Let every captain of a merchant ship, or commanding officer of a naval vessel, be furnished with the chart-book if he wishes for it. Let the central office wire to each institution or to each individual, according to terms which will be of advantage to the central office and to the institution or individual, a single message at any convenient hour. For example, "67" sent to all parts of the United Kingdom indicates that a shallow cyclonic circulation is slowly moving towards north-north-east over the Hebrides, but that an intensely well-developed *Nimbus* is advancing eastwards from the mouth of the English Channel. The book is opened everywhere to the same page on receipt of the telegram. If the ordinarily intelligent man who looks at the chart through the window of the office, institute, or public building, does not immediately know what to expect, he will very quickly acquire the art. As regards warnings to passing ships, it must not be forgotten that the large vessels of modern days are fairly independent, or soon will be fairly independent, of wind and wave, and that it is the smaller craft setting out from the fishing village which commonly suffer most. The crews of these latter can utilise the chart-book in the window before they decide upon their expedition. Nevertheless, to run up the group of digits on a "sky-sign" on an exposed and elevated piece of coast, at a signal office, a coast-guard station, a fort, a lighthouse, can be but the work of two or three minutes; and the officer of the vessel at sea, reading the group of digits through his glass, has only to open the chart-book in his cabin, and he knows what to expect in the way of weather in the course he intends to take. If all this be the stuff of which dreams are made, still dreams are not always useless. It is needless to mention here what benefit the farmer may receive in the harvest of corn or hay, in the seed-time, in the frost. Few have more admiration than the writer possesses for the skill exercised by the meteorological offices, and for the success of their forecasts; few, perhaps, for the activity at present noticeable in meteorological science. Yet when it is said, as it is often said, that weather-knowledge is almost at a standstill, it is impossible not to admit that this saying contains a kernel of truth. I hope that very soon, in any case, the wives and children of the sailor, the troubled soul of the agriculturist, will cease to call to us in vain.

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